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The GreCOR project: Green corridor benchmarking

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GreCOR GREEN CORRIDOR Oslo - Randstad

The Interreg IVB North Sea Region Programme

Investing in the future by working together for a sustainable and competitive region

The GreCOR project
Green corridor benchmarking

European Union The European Regional Development Fund

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List of abbreviations

BGLC	Bothnian Green Logistics Corridor
CEF	Connecting Europe Facility
CNC	Core Network Corridor
CO_2	Carbon dioxide
CO_2-eq	Carbon dioxide equivalent unit
CPI	Consumer Price Index
DS	Danish Statistical Bureau
ETF	Empty Trip Factor
EWTC	East-West Transport Corridor
GHG	Greenhouse Gas
GreCOR	Green Corridor in the North Sea Region
HES	Household Expenditure Survey
KPI	Key Performance Indicator
LCA	Life Cycle Assessment
LGV	Light Goods Vehicle
LNG	Liquefied Natural Gas
LF	Load Factor
LTM	Lands Trafik Modellen (Danish National Traffic Model)
NST	Standard goods classification for transport statistics
NTM	Network for Transport Measures
RFC	Rail Freight Corridor
SCANDRIA	Scandinavian-Adriatic corridor for innovation and growth
SECA	Sulphur oxide Emission Control Area
SGCI	Swedish Green Corridors Initiative
SOx	Sulphur oxides (SO_2 and SO_3)
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit (for containers)
TMS	Transport Market Study
WP	Work Package

Executive summary

This report presents the work performed and the results achieved under Activity 3.4 of the GreCOR project, which aims at developing a general method for measuring the environmental consequences of the operations in this green corridor including the logistic hubs.

The method developed here is a variation of the methodology proposed by the SuperGreen project for green corridor applications, which involves:

- disintegrating the corridor into transport chains;
- selecting a representative set of typical transport chains resembling the 'basket' of goods and services used for calculating the Consumer Price Index (CPI);
- estimating periodically KPI values for each and every chain of the selected sample; and
- aggregating these values into corridor-level KPIs by using appropriate weights and methods.

The GreCOR application reported here, which happens to be the first implementation attempt of the method after taking its final form described above, deviates from SuperGreen with regard to the main source of information. While SuperGreen suggests a 'study-based' approach using the Transport Market Studies of the TEN-T Core Network Corridors and/or the corresponding Rail Freight Corridors for constructing the corridor sample, timing constraints forced GreCOR to rely on a 'model-based' approach using the Danish National Traffic Model (LTM) as the principal source of information for both sample construction and KPI estimation.

After limiting the scope of the analysis to the Oslo-Randstad segment of the corridor, imposed by the use of LTM, the transport networks of GreCOR were viewed in conjunction with the TEN-T ScanMed and North Sea – Baltic core network corridors and its catchment area was defined.

The chain-matrix results of LTM for Year 2010, consisting of 2.9 million entries, was reduced to a database of 37,446 international chains originating and ending within the GreCOR catchment area.

Taking into consideration the special requirements that cargoes impose on all aspects of transport operations including the mode, vehicle types, loading units, handling equipment and facilities, business models, and even speed, ambient conditions, safety precautions, etc., the 23 commodities of LTM were rearranged to 13 commodity groups. For each commodity group, a small number of chains were selected reflecting the composition of the group by chain type. The criteria used for the selection included:

- the importance of a particular chain type relative to the total traffic,
- the degree of homogeneity in the range of services provided under a particular chain type, and
- the degree to which the various services covered by a chain type are subject to different influences and pressures in relation to the KPIs being used in the analysis.

A total of 156 chains formed the corridor sample. The annual tonnes and tonne*km (tkm) of these chains, which are used as weights in KPI aggregation, were adjusted to reflect also chain types not included in the sample.

Among the SuperGreen KPIs, the reliability of service indicator had to be dropped due to lack of data. The values of the cost (in DKK/tkm), average door-to-door speed (in km/h), frequency of service (in services/week), CO_2-eq (in g/tkm) and SOx (in g/tkm) indicators were estimated for each chain in the sample. The EcoTransIT World web-based tool was used for the CO_2-eq and SOx emission figures. SOx emission figures were corrected manually to take into consideration the stricter regulations on the sulphur content of marine fuels enforced as of Jan. 1, 2015 for the Emission Control Areas including all GreCOR waters. Cost figures were estimated on the basis of the LTM default values. A set of assumptions were used for the cargo handling and in-vehicle times of the chains, while the duration and frequency of the Ro-Ro and ferry services were based on actual schedules.

The weighted average approach was used for all KPI aggregations; tkm were used as weights for the cost, CO_2-eq and SOx indicators, while tonnes were the weights used for aggregating speed and frequency figures. For chain types represented by more than one chains for a commodity group, the chain weights were used to aggregate KPIs at the chain type level (Level 3). The adjusted tonnes and tkm were used for producing the commodity group (Level 2) aggregates, while the commodity tonnes and tkm were used as weights in calculating the corridor-level (Level 1) indicators.

A corridor index involving a normalisation procedure through setting the corridor-level values of each KPI to 100.0 was developed, allowing temporal and modal comparisons for a specific commodity or group of commodities. The corridor indexes by commodity group and chain type were produced. The modal indexes are shown below:

Mode	KPI Indexes				
	COST	SPEED	FREQ.	CO_2-eq	SOx
Road	344,6	217,5	23,3	113,9	80,4
Rail	79,0	154,4	14,0	69,5	50,1
Shipping	42,6	50,8	133,7	65,9	92,8
Ro-Ro shipping	158,1	233,9	14,4	540,2	284,9
Grand total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

The structure of the index permits comparisons between 1-leg and 3-leg arrangements or between containerships and conventional ships.

The basic conclusion is that the methodology described in this report can effectively assess the performance of a freight transport corridor. It can be further improved by:

- Excluding from the sample atypical chains identified during the analysis;
- Revising the sample with the aim of merging commodity groups that use the same type of vehicles and have similar characteristics in terms of the KPIs examined;
- Revising the sample with the aim of excluding chains that do not affect the corridor indexes (when expressed as one decimal point numbers);
- Dropping the frequency indicator from the analysis, which is meaningful only for scheduled services; and
- Calculating corridor indexes excluding shipping (Ro-Ro ships should not be excluded as they serve road transportation).

However, a major improvement would result from estimating chain-level KPIs through raw data obtained from specialised studies covering specific routes or directly from the stakeholders (shippers, freight forwarders and transport service providers) who use the relevant chains. It is believed that combining the 'model-based' approach for the sample construction with the 'study-approach' for the estimation of chain-level indicators takes advantage of the strengths of each method and avoids their weaknesses.

1. Introduction

1.1 General project description

GreCOR – Green Corridor in the North Sea Region – is an Interreg IVB North Sea Region project that promotes the development of a co-modal transport corridor in the North Sea Region.

This 42-month project that started on 1 Jan. 2012 has 13 partners and a total budget of € 3.7 million. The GreCOR corridor and the headquarters of its partners are shown in Figure 1. The project is led by the Swedish Transport Administration. In addition to its formal partners, GreCOR enjoys the active involvement of a number of relevant organizations, stakeholders and companies through the project's liaison group, which has been instrumental in promoting the goal of corridor development.

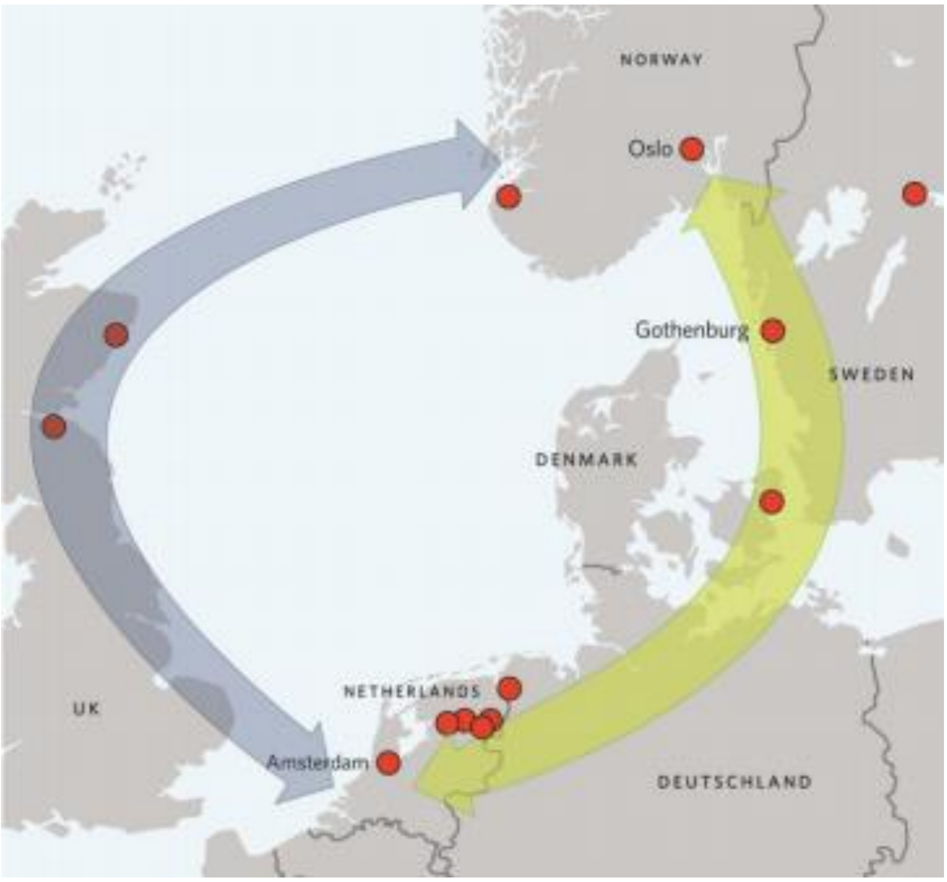

Figure 1. Map of the GreCOR corridor including locations of project partners. Source: CLOSER, 2014

GreCOR works in close collaboration with public and private stakeholders with an overall aim to implement the first green corridor in the North Sea Region in a strategic policy setting.

The main idea of the project is to influence the green corridor consisting of infrastructure and transport development in the area. Furthermore, GreCOR aims at:

- Improving knowledge about the logistics needs and conditions in the Oslo-Randstad corridor;
- Testing innovative logistics solutions through the development of pilot projects;
- Promoting the development of sustainable transport in the North Sea Region;
- Focusing on the role of the hubs and the regional hinterland; and
- Understanding and developing the logistics utility creation in a green corridor taking a co-modal perspective.

1.2 Activity objectives

The work process in GreCOR is divided into seven work packages. WP 1 relates to project management, while WP 2 is in charge of awareness and communication. The other five work packages, shown in Figure 2, concern the conceptual work of the project.

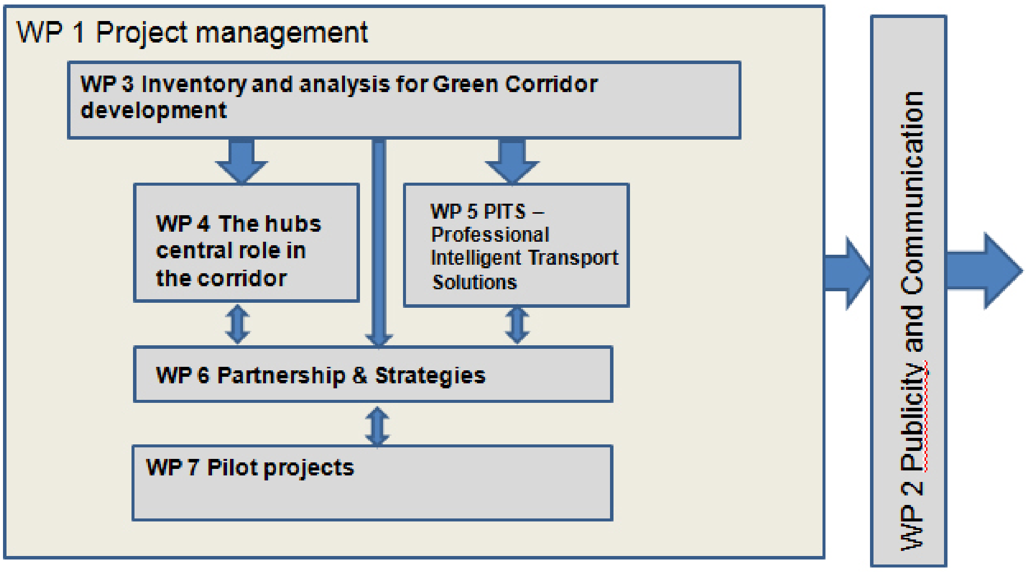

Figure 2. Structure of the GreCOR project. Source: GreCOR, 2014a

The objective of WP 3, which feeds to all other work packages, is the provision of the foundations for developing the first green corridor in the North Sea Region. It consists of the following activities:

- **Activity 3.1** Identification of freight flows and standard development
- **Activity 3.2** Mapping of on-going and planned projects and initiatives in the corridor and its catchment area
- **Activity 3.3** Analysis of bottlenecks and gaps in the transport system of the green corridor and the secondary network
- **Activity 3.4** Development of a general method for measuring the environmental consequences of the operations in the green corridor including the logistic hubs.

The work performed under Activity 3.4 and the results achieved are the subject of the present report. In fact, in addition to the environmental consequences prescribed in the abovementioned work description, the results will cover also economic and quality-related aspects of transport operations along the GreCOR corridor to the extent that data availability permits.

This extension of the scope of the activity became possible because the method developed here is a variation of the methodology proposed by the SuperGreen project for green corridor applications, which suggests a wider spectrum of performance indicators (SuperGreen, 2015).

1.3 Structure of the report

The report is organized in eight chapters. Chapter 2 that follows this introduction presents the methodology applied in assessing GreCOR. It covers all major facets of corridor benchmarking including the selection of Key Performance Indicators (KPIs), the construction of the sample and the collection of data. Due to the GreCOR focus on environmental issues, special emphasis is given to emissions estimation. Although the method was developed for this particular application, the chapter is written in a rather normative perspective strengthening the transferability of the approach to other similar applications.

Chapter 3 is devoted to the Danish National Traffic Model that is being used as the main source of information for the characteristics of the freight flows within the respective network. Although the model results were initially intended to be used exclusively for constructing the necessary sample of transport chains, it later turned out that are also valuable in KPI estimation.

Chapter 4 defines the corridor in terms of the modal networks considered. The relation of GreCOR to the TEN-T core network is then discussed and on the basis of this information, the catchment area of GreCOR is defined, which is used as a boundary for our analysis.

The construction of a sample of typical transport chains is the subject of Chapter 5. The criteria used for the chain selection and their application are presented here in detail.

Chapter 6 deals with the estimation of KPI values for the sample chains. The sources used for obtaining the necessary information are specified together with the calculation procedures. The results of each chain are presented in a tabular form.

The aggregation of the chain-level indicators to corridor-level ones is performed in Chapter 7, which also presents and discusses mode-level values.

The conclusions of Activity 3.4 are summarised in Chapter 8, which also presents recommendations for further development and refinement of the method applied here.

2. Methodology

The purpose of this chapter is to present the methodology that will be applied in assessing the performance of the GreCOR corridor. It comprises a variation of the methodology developed by the SuperGreen project for benchmarking green freight corridors. The explicit intention of GreCOR to "*implement the first green corridor in the North Sea Region in a strategic policy setting*" ensures the appropriateness of the SuperGreen methodology for this particular application.

The basic provisions of this methodology are summarized in the following headings of this chapter. For a more detailed discussion on methodological aspects, the reader is referred to the book "*Green Transportation Logistics: In Search of Win-Win Solutions"* (Psaraftis, 2015) and the SuperGreen "*Green Corridors Handbook – Volume II*" (Panagakos, 2012).

Before going further, it is important to emphasize that, although the method outlined below permits monitoring of the performance of a single corridor over time, it is not suitable for comparisons between corridors, as it does not consider differences in corridor characteristics that can be decisive in the overall performance of a corridor.

2.1 Benchmarking goal

Monitoring the performance of a transport corridor can serve several purposes. Obtaining a better understanding of the present conditions, identifying problems to be addressed, observing developments over time and comparing with benchmarks are some of them.

Also important is the perspective of the analysis. A multiplicity of actors is involved in a corridor and their priorities do not always coincide. A corridor consists of various types of services offered by competing operators through organized supply chains over a multimodal infrastructural network within an international regulatory and administrative framework. In a complex system like this, setting the exact purpose of the analysis and its intended use is essential.

A clear goal statement assists decision making throughout the analysis and affects all subsequent tasks. In general, it should be kept in mind that due to resource limitations, there is a trade-off between the width and the depth of analyses of this sort.

No specific goal statement is provided for the present application, which basically serves demonstration purposes. The overall GreCOR objective of developing a green corridor has not been further decomposed into specific objectives. This fact prevents the formulation of a meaningful goal statement for further use in the sense described above.

2.2 Corridor description

The next task cannot be different than defining the corridor under investigation. As can be inferred from Chapter 4, corridors tend to be described by locations that represent rather broad geographical areas/places where the corridors start, end or pass through. This has to be translated into a more detailed definition that includes the modes to be examined and the routes comprising the corridor.

Each route should be described as a set of designated links, terminals and supporting facilities. Parallel secondary links or by-passes should be mentioned only as enhancing the resilience of a corridor. For benchmarking purposes, only existent links should be designated to a route.

The GreCOR corridor is described in Section 4.1.

2.3 KPI selection

The performance of a corridor needs to be assessed in terms of pre-specified qualities that correspond to the objectives pursued by the corridor management. Monitoring is achieved through a set of Key Performance Indicators (KPIs), which is defined either explicitly (e.g. in the Brenner corridor (Mertel and Sondermann, 2007), Corridor Rhine-Alpine (Corridor A, 2011), East-West Transport Corridor (Fastén and Clemedtson, 2012), Bothnian Green Logistics Corridor (Öberg, 2013), the Swedish Green Corridors Initiative (SGCI, 2012) and the SuperGreen project) or implicitly (e.g. in the Scandria (Friedrich, 2012), TransBaltic (TransBaltic, 2012), and STRING (Stenbæk et al., 2014) projects).

Arnold (2006) proposes the use of cost, time, reliability and flexibility as the most important KPIs. The management of Corridor A (Rotterdam-Genoa) has selected indicators concerning traffic volume, modal split, punctuality and commercial speed. The defined quality objectives of the BRAVO project (Brenner corridor) were punctuality, reliability, flexibility, customer information, employment rate of agreed rolling stock, and reliability of transport documents.

The SuperGreen project, after extended consultation with freight logistics stakeholders, proposes the following set of KPIs for corridor benchmarking applications:

- Out-of-pocket costs (excluding VAT), measured in €/tonne-km,
- Transport time, measured in hours (or average speed, measured in km/h, depending on the application),
- Reliability of service (in terms of timely deliveries), measured in percentage of consignments delivered within a pre-defined acceptable time window,
- Frequency of service, measured in number of services per year,

- CO_2-eq emissions, measured in g/tonne-km, and
- SOx emissions, measured in g/tonne-km.

Among them, the cost indicator is the most difficult one to calculate due to the scarcity of relevant data. In such cases, the volume of cargo moved along the corridor can serve as a proxy for describing its efficiency.

It needs to be emphasized here that KPIs should be selected by the corridor management on the basis of the specific objectives that are being pursued. Given the absence of specific objectives for the GreCOR project, it was decided to use the KPIs proposed by the SuperGreen project.

2.4 Methodological principles

Unlike KPIs, corridor benchmarking is not a very popular topic in the literature. Most benchmarking work stops at the transport chain level. The few exceptions found in the bibliography include the World Bank's *"Best Practices in Management of International Trade Corridors"* (Arnold, 2006) and the EWTC's "*Green Corridor Manual*" (Fastén and Clemedtson, 2012).

Given that a corridor is generally a composite system, both these reports suggest: (i) decomposing the corridor into alternative "routes" (the former) or "services" (the latter), (ii) selecting an appropriate sample of routes/ services, and (iii) measuring the performance of each selected route or service. However, neither of the two describes the method for assessing the corridor as such.

SuperGreen has added a fourth step in this process, which is summarized below:

Step 1. Disintegrate the corridor into transport chains[1].
Step 2. Select a representative set of typical transport chains.
Step 3. Estimate KPI values for each and every chain selected in Step 2.
Step 4. Aggregate these values into corridor level KPIs by using appropriate weights and methods.

In addition, SuperGreen has suggested keeping the 'basket' of typical transport chains constant and monitoring performance periodically in a way resembling the functionalities of the Consumer Price Index (CPI) calculated by the statistical bureaus around the world.

[1] In this report, the term 'transport chain' denotes a combination of services offered along a route (alignment) of a transport corridor.

2.5 Sample construction

In the CPI context mentioned above, the basket of goods and services used for CPI calculations is selected on the basis of the so-called Household Expenditure Survey (HES) that provides information on the spending habits of the population under examination (Pink, 2011). In a freight corridor context, the equivalent information relates to the preferences of the shippers among the alternative available transport chains. This information can derive either from existing studies (‘study-based approach’) or model results (‘model-based approach’).

The main strength of the study-based approach relates to the accuracy of the information, which is usually the result of a focused analysis approved by the relevant authorities. Its weaknesses include information unavailability, either because of lacking studies outside the corridor “hot spots” or because of confidentiality restrictions, and coherence problems due to differences in scope, time horizon, non-harmonized base assumptions, etc.

On the other hand, the model-based approach provides a comprehensive and coherent picture of all flows on each section of the corridor but suffers from limited accuracy of the results due to a set of underline assumptions (sometimes hidden in a black-box). Of course, the accuracy of model results improves with the quality of its calibration which, however, requires extensive use of observed traffic data on the network that, in turn, is not always available and can be very expensive to obtain.

As will be shown in Section 4.2 (refer to Figure 8), there is significant overlap of the GreCOR corridor with three TEN-T core network corridors. In view of this fact, it was initially thought to construct the sample on the basis of information contained in the Transport Market Studies (TMS) of these three core network corridors, as well as the studies of the corresponding Rail Freight Corridors (RFCs). However, it was soon revealed that the TMS of both the Scandinavian-Mediterranean RFC and the ScanMed TEN-T core network corridor that cover a good part of GreCOR extending from Oslo to Hannover would not become available until November 2014. This timing left no possibilities for use in the framework of the present study. It was, thus, decided to proceed with the model-based approach.

The international character of GreCOR calls for a model covering effectively all corridor segments. In this respect, the European TRANS-TOOLS model (Ibánez-Rivas, 2010) would be an ideal source of information. Although DTU is actively involved in updating this model, its completion schedule was, once again, not compatible with the time plan of this study. Instead, we were forced to rely on the Danish national transport model, which was recently (2014) updated by DTU and could prove effective for a considerable part of the corridor due to the location of Denmark in the middle of GreCOR alignment.

2.6 Data collection and verification

The task relates to the information needed for calculating KPI values for each and every transport chain of the sample. In the CPI context, a representative sample of outlets is constructed for each and every item in the 'basket' for soliciting price information. In our case, the equivalent process would include the following actions:

- a sample of transport providers and major shippers is formed for soliciting information,
- a questionnaire is prepared for gathering the necessary information,
- follow-up actions are foreseen for data collection including interviews if necessary, and
- a procedure addressing missing observations and quality adjustments is designed.

The available resources, however, do not permit the application of this detailed information gathering campaign in the framework of this project. Instead, we have to rely on readily available information from official statistics and other sources.

As a general rule, the reported values should be:

- **Consistent:** The methodology employed should be consistent to allow for meaningful comparisons over time. Any changes to data, system boundaries, methods or any other relevant factor in the time series has to be clearly documented.
- **Transparent:** All relevant issues need to be addressed in a factual and coherent manner. The underline assumptions, calculation methodologies and data sources used have to be disclosed.
- **Accurate:** Ensure that uncertainties are reduced as far as practicable. Values reported should be of sufficient accuracy to enable users to make decisions with reasonable assurance as to the integrity of the reported information.

Confidence in the quality and integrity of the data not only supports internal operations by revealing existing problems or points for potential improvement but also addresses external stakeholder requirements for transparency in sustainability issues by demonstrating:

- the credibility and reliability of the corridor data,
- the consistency and accuracy of the performance monitoring approach, and
- the completeness of the assessment.

Verification is an independent assessment of the accuracy and completeness of data and can provide confidence that the values reported are fit for the purpose for which they are intended, for example, target setting or service benchmarking. In the case of monitoring a complex system such as a transport corridor, the fully-fledged analysis should be verified by a third party accredited by an internationally recognised body. Especially for greenhouse gas (GHG) emission reporting, there are a number of internationally recognised standards and protocols that can be applied, like:

- ISO14064 – Greenhouse gas accounting,
- ISO14065 – Requirements for greenhouse gas validation and verification bodies for use in accreditation or other forms of recognition, and
- ISO 16258 – Methodology for calculation and declaration of energy consumption and GHG emissions of transport services (freight and passengers).

2.7 Emission estimation

When it comes to emissions, the definition of system boundaries is crucial in fulfilling all three criteria mentioned above (consistency, transparency and accuracy). Swahn (2010) defines four system boundaries (refer to Figure 3):

- System boundary A includes transport activities involving engine operation for the propulsion and climate control of goods, as well as losses in fuel tanks and batteries. This boundary also includes the traffic-related terminal handling, i.e. when goods do not leave their vehicle/vessel.
- System boundary B includes in addition the supply of energy from energy source to the tank, battery and electric motor (trains). This is the minimum required system boundary for performance of comparisons between different modes of transport.
- System boundary C includes in addition traffic infrastructure operation and maintenance.
- System boundary D includes in addition vehicle, vessel and load units production and scrapping (life cycle approach).

Although the introduction of the Life Cycle Assessment (LCA) methodology in gaining importance, it is essential to keep things as simple as possible in the early stages of a green corridor development. It is for this reason that the system boundary B is recommended for GreCOR to begin with. Later on, the boundary can be expanded to reach level D.

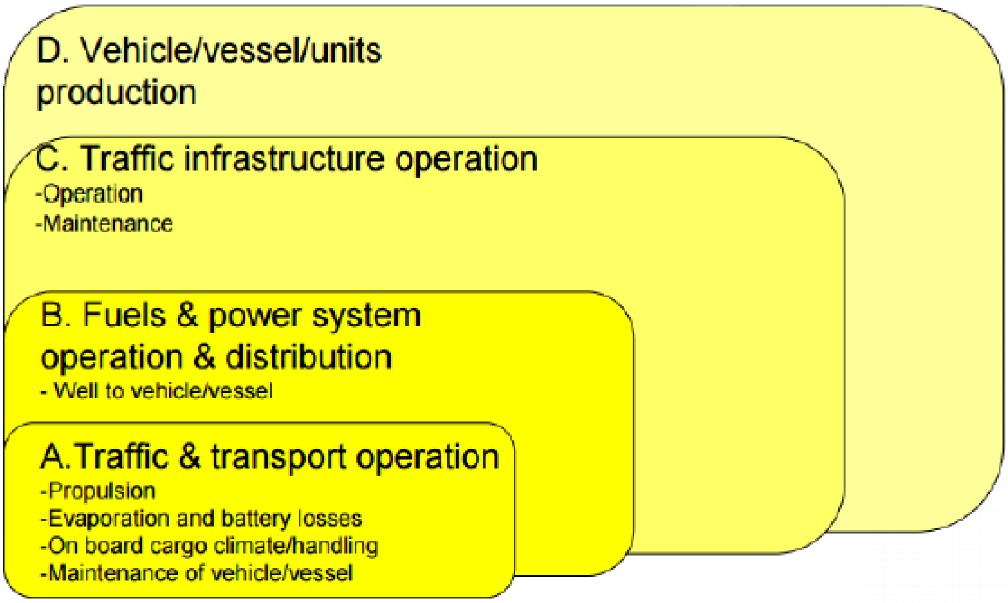

Figure 3. Definition of system boundaries. Source: Swahn (2010)

Another comment relates to the type of carbon emissions measured. In discussing emissions, lots of terms are used – carbon emissions, carbon dioxide, greenhouse gases (GHGs). In fact, climate change is caused by a range of gases, known collectively as 'greenhouse gases'. Of these, the most common is carbon dioxide (CO_2). However, other GHGs are emitted from vehicle exhausts (i.e. nitrogen dioxide and methane), and their reporting is also valuable. This is done through CO_2-equivalent (CO_2-eq) units expressing GHGs as if they had the same climate change effects as CO_2. The choice between CO_2 and CO_2-eq depends on the availability of data and/or the capabilities of the emissions calculator used. CO_2-eq, if available, is preferable to CO_2.

In general, a specialized emission calculator is needed for estimating the emission KPIs. In GreCOR, the web-based tool EcoTransIT World will be used but, as long as certified footprint calculators are not available, any other model could have been used in its position, provided that a relevant qualification escorts the results. In the framework of the BGLC project, Öberg (2013) compared EcoTransIT World with NTM, a Swedish emission calculator, with inconclusive results. The announced cooperation between the two models towards creating synergies in their methodological expertise on carbon accounting is welcomed (EcoTransIT, 2014).

In relation to emission calculators, it should be mentioned that user specified inputs are preferred to any model's default values, only when they are adequately verified and there is consistency across all chains examined. Otherwise, it is safer to use the default values of the selected model.

2.8 KPI aggregation

The weights needed for aggregating chain-level KPIs into corridor-level ones depend on the relative significance of each chain in the route it belongs and in the entire corridor. As such, they have to be determined by using the model results that were considered in constructing the chain basket. These weights should be relatively fixed to permit historical comparisons.

It is noted that normally the weights for aggregating unit costs, CO_2 and SOx emissions should be in tonne-km units. Transport time can only be aggregated if expressed as average speed, unless all chains examined concern a single origin-destination pair. The volume of cargo is probably the most suitable weight for aggregating transport time (or speed) and reliability. As for frequencies, one needs to be careful to avoid adding pears with apples. As a general rule of thumb, in serial services it is the least frequent one that determines the frequency of the chain.

2.9 Benchmarking periods

The frequency of monitoring the performance of a corridor depends on the objectives set by the corridor management. As far as transport services are concerned, an annual benchmarking is both feasible and practical, especially if customer satisfaction needs to be reported which happens to be the case with Rail Freight Corridors (Reg. 913/2010). Infrastructural developments can be reported on a less frequent basis.

A relevant issue relates to the periodical adjustments needed to account for changes in the composition of cargoes and transport chains that use the corridor. As changes of this sort would affect the model results (and the corresponding chain basket and weights), they can only be accounted for whenever the model is updated. In the CPI context, the HES is usually updated every 5-7 years.

3. The Danish National Traffic Model

The recently updated (2014) Danish National Traffic Model (LTM-Lands Trafik Modellen) provides a unified reference that serves as the basis for transport policy analyses in Denmark. It has been designed as a tool for answering questions related to potential developments in the economy, the policy framework and the country's transport infrastructure. For example, it can forecast the consequences of:

- economic developments in Denmark and abroad;
- the construction of a new fixed link across the Fehmarn Belt;
- the introduction of new roads, ports and train services;
- the establishment of new ferry and container connections;
- the development of new distribution centres;
- the introduction of big trucks (gigaliners);
- the introduction of toll schemes of various types including environmental taxes, congestion charges, etc.; and
- other changes in the transport cost structure including inventory and distribution activities.

3.1 Structure of the model

The overall structure of the model is illustrated in Figure 4. Firstly, exogenous variables like population forecasts, the transport network and employment forecasts are defined and fed into the model.

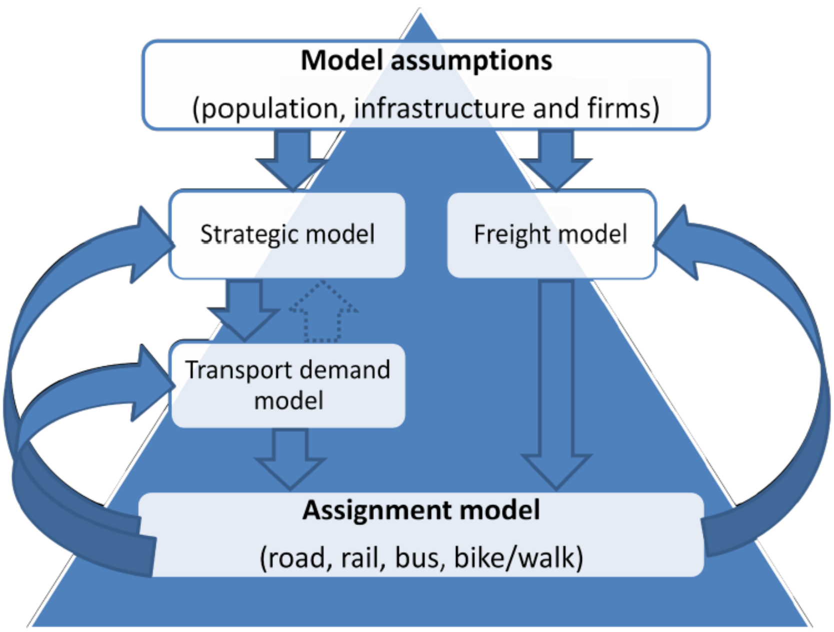

Figure 4. The overall model structure. Source: Rich et al. (2010)

At a second stage, the model calculates aggregate passenger and freight demands through two parallel blocks. The passenger block is further decomposed into two sequentially linked parts: (i) a strategic model, which handles household based decisions concerning residential location, work location(s) and car ownership, and (ii) a demand model. At the next stage, both passenger and freight blocks affect the modal split and the route choice equilibrium, which in turn spills back on the demand. Due to the nature of the GreCOR project, the discussion in the remainder of this section is limited to the freight part of LTM.

3.2 Scope of the model

In terms of geographical coverage, the model handles all types of goods movement related to Denmark, i.e.:

- national transports within Denmark;
- international transports to and from Denmark;
- transit transports through Denmark; and
- transport which may be transferred to transit through Denmark, for example by a new fixed link across the Fehmarn Belt.

Table 1 below provides the daily cargo flows (in tonnes) transported during the base year (2010) between producers and consumers in the countries of interest as estimated by the model.

Table 1. Base year (2010) Producer/Consumer flows[2]

Producer/Consumer flows (two directions)	Tonnes per day
Internal within Denmark	356,714
Denmark – Sweden	43,948
Denmark – Norway	30,741
Denmark – Finland	7,831
Denmark – Europe	168,812
Sweden – Europe	357,678
Norway – Europe	606,630
Finland – Europe	392,824
Denmark – abroad	39,271
Sweden/Norway/Finland – abroad	46,429
Total	2,050,879

[2] Tables and figures without a specific reference to an external source in their caption have been compiled by the publisher of the report.

For more disaggregated figures, the world is divided in 351 zones, of which:

- 176 are located in Denmark (at sub-municipality level delineating clearly divided centres);
- 119 in Europe; and
- 56 in the rest of the world.

The European zones of the model appear in Figure 5 below.

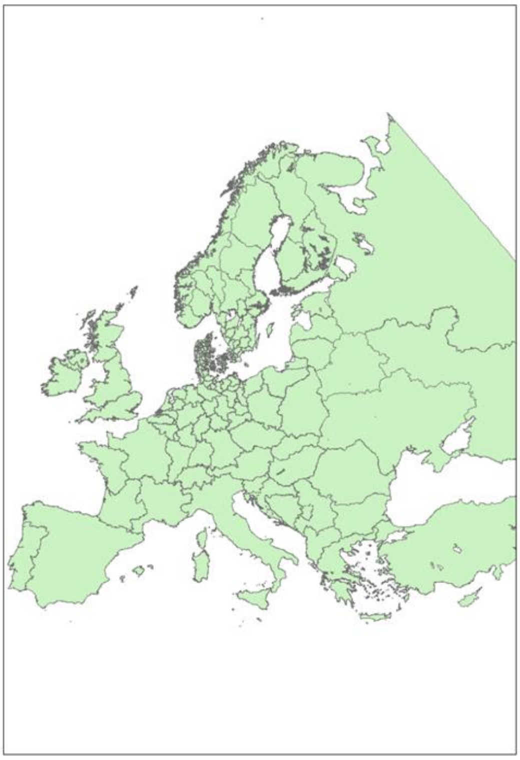

Figure 5. Denmark and Europe as they appear in the model's zonal system

The commodities covered by the model are those of Table 2 according to the nomenclature of the standard goods classification for transport statistics (NST 2007). The same table provides the daily Producer/ Consumer cargo flows by commodity type for Year 2010.

In terms of modes, the model is designed to handle road, rail and maritime transport. For road transport, the model distinguishes among the following 8 vehicle types:

- light goods vehicle (LGV);
- truck 3,5 – 12 tonnes;
- truck 12 – 18 tonnes;
- truck 18 – 26 tonnes;
- truck with trailer 12 -18 tonnes;

Table 2. Daily Producer/Consumer flows by commodity type (NST 2007) for Year 2010

ID	Commodity type	Tonnes per day
1	Products of agriculture, hunting, forestry and fish	162,299
2	Coal and lignite	78,287
21	Crude petroleum and natural gas	397,102
3	Iron ores and uranium and thorium ores	60,144
22	Chemical and natural fertilizer	34,325
23	Salt, stone, sand, gravel etc,	166,769
4	Food products, beverages and tobacco	120,762
5	Textiles and textiles products, and leather and leather products	14,602
6	Wood and wood products (except furniture), and paper products	194,356
7	Coke and refined petroleum products	251,984
8	Chemicals, rubber and plastic products	147,474
9	Other non-metallic mineral products	62,242
10	Basic metals, fabricated metal products except machinery	93,834
11	Machinery, radio, TV, computers, optical instruments etc,	73,222
12	Transport equipment	18,978
13	Furniture and other manufactured goods	79,973
14	Secondary raw materials, municipal wastes and other wastes	50,832
15	Mail and parcels	27,040
16	Equipment and material utilized in transport of goods	998
17	Goods moved in the course of household/office removal, baggage	4,203
18	Mixture of types of goods transported together	11,451
	Total	2,050,879

- truck with trailer >18 tonnes;
- articulated truck; and
- gigaliner.

As for rail transport, three vehicle configurations are used:

- conventional train;
- combined truck-on-train; and
- short wagon train.

The ship types handled by the model are:

- Ro/Ro – ferry;
- containership; and
- conventional bulk carrier.

3.3 Model output

In terms of cargo flows, three types of matrices are produced by the model:

PC-matrices:	Describe goods flows in tonnes between the producer (P) and the consumer (C) by commodity group.
OD-matrices:	Describe the separate legs of a transport between P and C. They provide: (a) annual cargo volumes by mode of transport and commodity group, and (b) the corresponding number of vehicles, trains or ships used.
Chain matrices:	Describe a chain of OD combinations with cargo volumes or vehicles between P and C. A maximum of three legs is permitted for describing a chain matrix (refer to Figure 6).

Figure 6. An example of a 3-leg chain consisting of a maritime connection served by trucks for the first and last miles

In broad terms, the PC-matrices that result from the trade model based on macroeconomic forecasts are disaggregated into firm-to-firm flows depending on the number of firms and employees (stochastic model). A logistics model, then, selects the most favourable transport chain for each flow through minimising the total annual logistics cost. This involves the choice of shipment size, the choice of load unit (e.g. container or not), the choice of transhipment for distribution, consolidation and intermodal transport, and the assignment of a mode per leg.

The function that is minimised by the logistics model is the total annual logistics costs of commodity *k* between firm *m* in production zone *r* and firm *n* in consumption zone *s* of shipment size *q* with chain *l*, as given by the formula:

$$G_{rskmnql} = o_k \frac{Q_k}{q_k} + T_{rskql} + \mathrm{ijgv}_k Q_k + (\mathrm{it}_{rsl} v_k Q_k + \frac{\mathrm{iv}_k q_k}{2}) + \frac{w_k q_k}{2} + Z_{rskq}$$

where:

o = order cost (user input);

Q = annual demand in tonnes;

q = average shipment size;

T = transport, consolidation and distribution costs (capacity, load, distance and time costs are user inputs as per Table 3);

i = discount rate;

j = fraction of the shipment that is lost or damaged during transport;

g = average period to collect a claim;

v = value of goods (user input);

t = transport time;

w = storage costs (user input); and

Z = stock-out costs.

Table 3. Default cost figures for road transport (Year 2010)

Type description	Capacity Ton	Load cost kr/ton	Distance cost kr/km	Time cost kr/h	Ferry cost kr/h
LGV	1	0,7	2,65	170,1	68,04
Truck 3,5-12 t	3	6,5	3,08	187,22	74,89
Truck 12-18 t	5	7	3,39	195,91	78,36
Truck 18-26 t	9	7	5,53	248,17	99,27
Truck w/trailer 12-18 t	7	7	3,83	242,04	96,82
Truck w/trailer >18 t	11	7	6,32	309,45	123,78
Articulated truck	17,2	7	6,65	364,27	145,71
Gigaliner	22	24	9,64	384,72	153,89

As a final step, the OD-matrices are calculated through aggregating transport legs between zone pairs and after correcting for empty vehicle trips.

The Denmark-related daily OD-flows for the base year (2010) are shown in Table 4 by transport mode, and their total is compared to the corresponding PC-flows of Table 1.

It is worth mentioning that in general the OD-flows are expected to be higher than the corresponding PC-figure due to the fact that any single PC pair can contain up to three OD ones. The different behaviour observed in the Denmark-Norway and Denmark-Finland pairs is explained by the fact that a number of OD-flows pertaining to these PC-pairs are reported in the Denmark-Sweden flows, as the relevant transport solutions involve transiting Swedish territory.

Table 4. Daily OD-flows by mode related to Denmark (Year 2010)

OD-flows	Truck	Train	Ship	Total	Tonnes in PC-matrix
Within Denmark	579,355	3,036	26,447	608,838	*356,714*
Denmark – Sweden	44,884	906	29,425	75,215	*43,948*
Denmark – Norway	3,724	816	20,676	25,216	*30,741*
Denmark – Finland	387	0	4,941	5,328	*7,831*
Denmark – Europe	97,950	4,603	66,643	169,196	*168,812*
Total	726,300	9,361	148,132	883,793	*608,046*

3.4 Data sources

For the base year (2010), the construction of the OD-matrices was based on the following data sources:

Danish national LGV and truck trips

- National incept survey (49 locations)
- Official statistics of the Danish Statistical Bureau (DS)
- Firm interviews (Arla, waste, gigaliner)

Danish international truck trips

- Port and bridge incept survey
- DS and Scanlines data
- ITD-count data (counter of trucks at the borders on a 3-month basis)
- NUTRADA survey (truck plate monitoring at the borders)
- Stop interviews at the Great Belt
- TRANS-TOOLS model results

Maritime transport

- Danish port and ferry statistics
- TØI (2010) model results [Norwegian model]
- GORM (2003) model results [Danish/Swedish freight model]
- Foreign trade statistics

Rail transport

- Danish rail statistics
- TØI (2010) model results [Norwegian model]
- GORM (2003) model results [Danish/Swedish freight model]
- Foreign trade statistics.

For the construction of the PC-matrices, the Swedish Samgods and CFS 2009 models are used in addition to the above mentioned sources.

4. The GreCOR corridor

4.1 The GreCOR modal networks

As mentioned in Section 2.2, one of the first tasks to be done for benchmarking a corridor is to define the specific networks to be analysed. For the GreCOR application, we will consider road, rail and maritime transport. The corresponding networks appear in Figure 7.

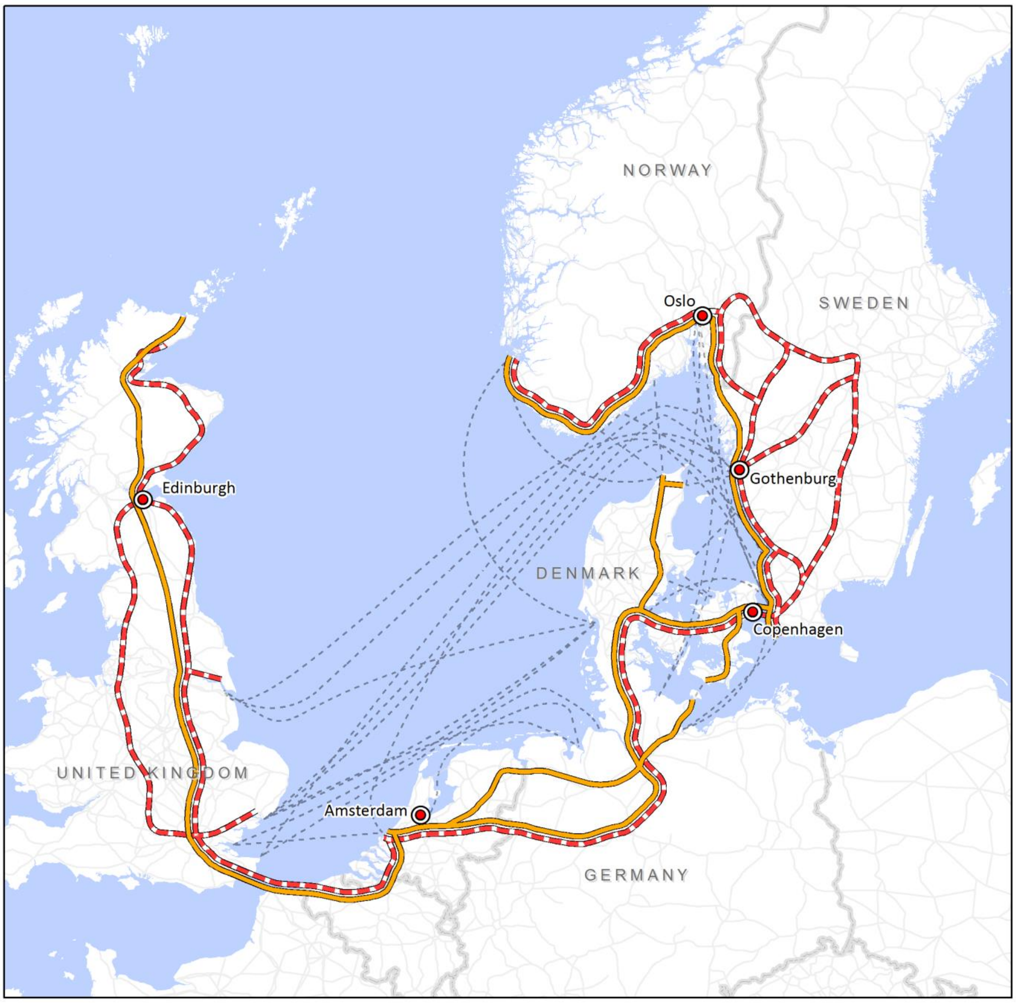

Figure 7. The modal networks of GreCOR. Source: GreCOR, 2014b

The road network of the corridor starts at Stavanger (NO) and follows the north-south route E39 to Kristiansand via Sandnes, Ålgård, Helleland, Flekkefjord, Lyngdal and Mandal. Kristiansand is connected by ferry to Hirtshals (DK) and Aalborg, where E39 meets E45. The European route E18 connects Kristiansand to Oslo via Arendal, Porsgrunn, Larvik, Sandefjord, Tønsberg, Horten and Drammen. In Oslo E18 intersects the north-south route E6, which heads towards the Norwegian/Swedish border through Moss, Sarpsborg and Halden. After crossing the border, E6 follows the western coastline of Sweden to Malmö and Trelleborg via

Svinesund, Gothenburg, Halmstad and Helsingborg. Gothenburg is connected by ferry to Frederikshavn (DK) and from there to Aalborg and E45.

The east-west axis E20 connects Malmö to Copenhagen via the Øresund Bridge. After passing Køge on its westbound direction, E20 crosses the Great Belt Bridge to reach Odense and, from there, the Little Belt Bridge to reach Fredericia and Kolding. In Kolding E20 intersects E45 that follows a north-south path from Aalborg to Hannover through Randers, Århus, Vejle, Kolding, Frøslev, Flensburg (DE) and Hamburg.

The road network of GreCOR includes another alternative for the Copenhagen – Hamburg link. In involves E47, which coincides with E20 on the Copenhagen – Køge segment, but then continues southward to Rødby. A ferry connects Rødby (DK) to Puttgarden (DE) across the Fehmarn Belt. E47 extends further south and ends at the port city of Lübeck, which is connected to Hamburg via E22. It is worth mentioning that the ferry connection between Denmark and Germany will be replaced by a fixed link by year 2020, as the construction of a tunnel is expected to begin soon.

Route E22 connects Hamburg to Amsterdam through Bremen, Oldenburg, Leer, Bunde, Nieuweschans (NL) and Groningen. Amsterdam is further connected to the other Randstad ports of The Hague, Rotterdam and Antwerp (BE) through E19. An alternative routing connecting Hamburg to the Randstad region is through E45 to Hannover, then E30 to Utrecht via Bad Oeynhausen, Bünde, Osnabrück, Bad Bentheim, Hengelo (NL), Deventer, Apeldoorn and Amersfoort, and then E25 to Rotterdam. Route E17 connects Antwerp to Ghent, which is further connected to Bruges/Zeebrugge, Ostend, Dunkirk (FR) and Calais through E40.

Trucks cross the English Channel either through a number of ferry links like Calais-Dover, Dunkirk-Dover, etc. or on board trains crossing the Eurotunnel with up to 1 departure every 10 minutes at peak times (Eurotunnel, 2015). From Dover, E15 leads north to Inverness, Scotland through London, Newcastle upon Tyne, Edinburgh and Perth. A9 goes further north to Thurso.

The main GreCOR railroad line runs in parallel to E39 (from Stavanger to Kristiansand), to E18 (from Kristiansand to Oslo), to E6 (from Oslo to Malmö), to E20 (from Malmö to Kolding), to E45 (from Kolding to Hannover), to E30 (from Hannover to Utrecht), to E25 (from Utrecht to Rotterdam), to E19 (from Rotterdam to Antwerp), to E17 (from Antwerp to Ghent), to E40 (from Ghent to Calais), and after crossing the Eurotunnel, to E15 (from Dover all the way up to Helmsdale, Scotland).

In addition to this main line, the network includes the alternative routing between Oslo and Malmö via Charlottenberg, Kil, Karlstad, Örebro, Hallsberg, Mjölby and Hässleholm. In Sweden, the network also includes the connections Gothenburg-Kil, Gothenburg-Hallsberg and Halmstad-Hässleholm. In the UK, the West coast main line between London and Edinburgh is also included in the GreCOR rail network as an alternative routing.

As for the waterborne transport, the North Sea and the Baltic Sea are among the most trafficked zones in the world. In addition to the tramp shipping that carries mainly dry and liquid bulk cargoes between any pair of ports (provided that are equipped for such trades), there are decades of liner (scheduled) connections between the ports of the region employing Ro-Ro, Ro-Pax and container ships. Figure 7 shows only a limited number of Ro-Ro and ferry links: Gothenburg/Brevik-Immingham, Gothenburg/Brevik-Ghent, Esbjerg-Immingham, Esbjerg-Stavanger, Esbjerg-Zeebrugge, Esbjerg-Amsterdam, Tilbury-Rotterdam-Helsingborg, Tilbury-Zeebrugge-Antwerp-Lübeck, Bremen-Sheerness, Bremenhaven-Harwich-Cuxhaven, Stavanger-Hirtshals, Hirtshals-Larvik, Frederikshavn-Oslo, Odden-Aarhus, Fredericia-Copenhagen, Kiel-Gothenburg, Kiel-Oslo, Lübeck-Malmö, Lübeck-Trelleborg and Copenhagen-Oslo.

4.2 GreCOR and the TEN-T core network

Almost two years after the commencement of GreCOR, in December 2013, the EU launched a major overhaul of its transport infrastructure policy by adopting the new TEN-T Guidelines (EP&C, 2013a) and establishing the Connecting Europe Facility (CEF), which will govern EU funding until 2020 (EP&C, 2013b).

The new TEN-T Guidelines introduced a dual layer network structure, consisting of a comprehensive and a core network. The comprehensive network constitutes the basic layer of the TEN-T and is, in large part, derived from the corresponding national networks. It has to be completed by 2050. The core network, on the other hand, overlays the comprehensive network and contains its strategically most important parts. It has to be put in place by 2030. To facilitate implementation of the core network, the Guidelines introduced the instrument of "Core Network Corridors" (CNC) – a coordination tool aiming at coherent project implementation and at promoting technological, operational and governance-related innovation. Stricter technical specifications are prescribed for the CNCs, which are eligible for priority funding through the CEF.

Although the CNCs are broader in scope than the green corridors in the sense that they cover both freight and passengers and include aviation in addition to surface modes, it is interesting to note the considerable overlap that exists between GreCOR, a green corridor, and the TEN-T core network.

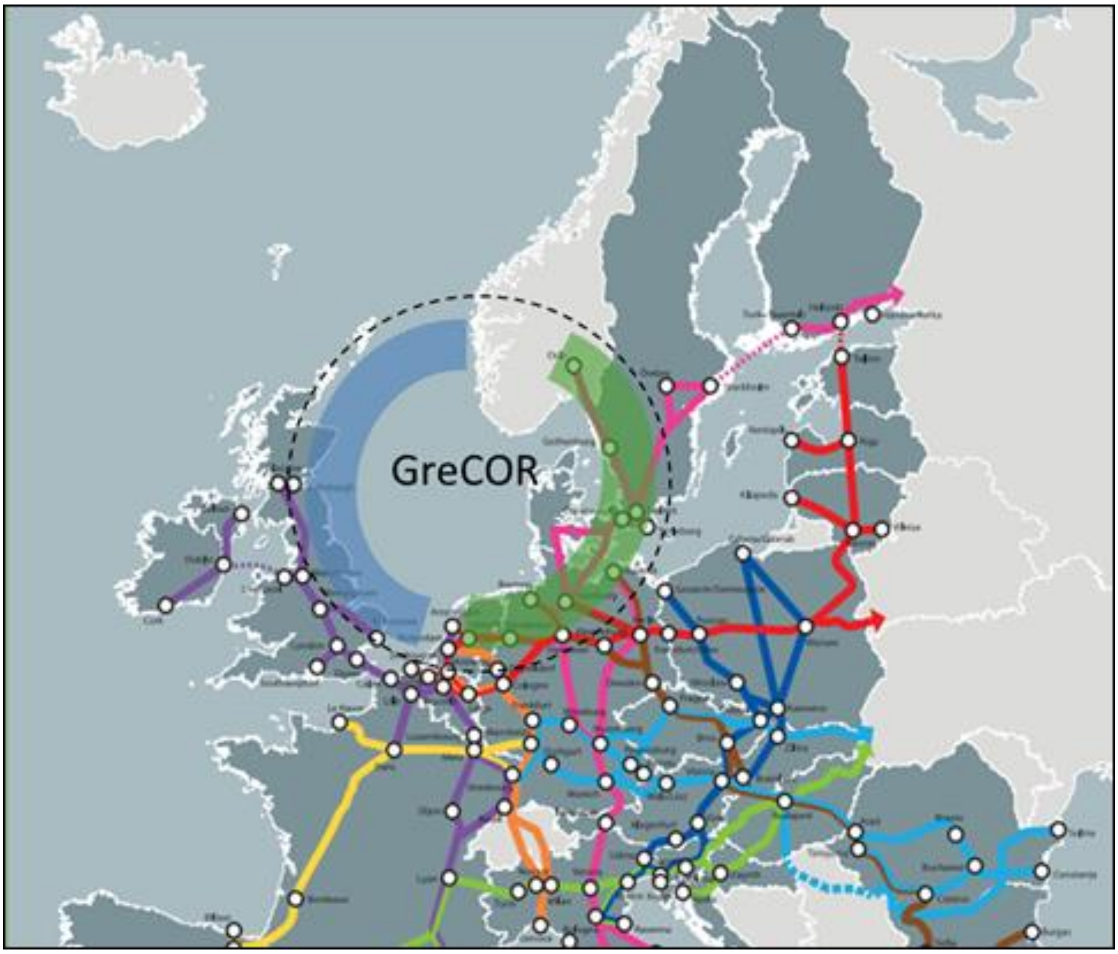

Figure 8. GreCOR and the TEN-T core network. Source: GreCOR, 2014c

As shown in Figure 8, GreCOR overlaps macroscopically with three CNCs:

- The Scandinavian - Mediterranean corridor linking the major urban centres in Germany to Scandinavia (Oslo, Copenhagen, Stockholm and Helsinki) and the Mediterranean (Italian seaports, Sicily and Malta) [pink coloured in Fig. 8];
- The North Sea – Baltic corridor joining the Baltic Sea Region in northeast with the four largest European ports (Rotterdam, Antwerp, Hamburg and Amsterdam) in the low countries of the North Sea Region [red coloured in Fig. 8]; and
- The North Sea - Mediterranean corridor stretching from Glasgow and Edinburgh in the north to the Randstad region up to Amsterdam in the centre, to Paris and Marseille in the south [purple coloured in Fig. 8].

The basic rationale of the corridor approach relates to the creation of economies of scale by consolidating considerable volumes of cargo along specific routes. These economies enable the efficient use of more environmentally friendly modes like rail and waterborne transport, the creation of a network of refuelling stations for alternative clean fuels and, in general, the enhancement of the efficiency of transport operations along the corridor. Viewed from this perspective, the alignment of a corridor and the specific routes included need to be considered very carefully.

The central role of the CNCs in the European transport policy necessitates the reviewing of all extant corridor schemes. In fact, the CEF Regulation demands the re-alignment of the Rail Freight Corridors (RFCs) in line with the corresponding CNCs (EP&C, 2013b). So, how does GreCOR compare to the three overlapping CNCs?

Before answering this question, we need to consider a more practical issue. As mentioned in Chapter 3, GreCOR will be assessed on the basis of the Danish national traffic model (LTM). By definition, the accuracy of LTM results drops with the distance from Denmark. The LTM zonal system of Figure 5 is indicative. Given that the share of Denmark in the external trade of the UK was in the order of 1% for both imports and exports in 2010 and that of all Scandinavian countries (DK, SE, NO, FI) was less than 9% for imports[3] and 5% for exports (Eurostat, 2011), it was decided to exclude the UK from the analysis. By the same token, the Norwegian part Stavanger-Oslo was excluded limiting the analysis to the Oslo-Randstad segment. Actually, as shown in Figure 9, this is in line with other GreCOR deliverables.

The Oslo-Randstad segment of GreCOR can be split into two parts: Oslo-Hannover and Hannover-Randstad. The former needs to be compared to the Scan-Med CNC (refer to Figure 10) and the latter with the North Sea-Baltic corridor (refer to Figure 11).

With regard to Oslo-Hannover, the following differences can be spotted between GreCOR and the Scan-Med CNC:

- the Oslo-Hallsberg rail link of GreCOR is missing from the CNC, as well as the connections Gothenburg-Kil, Gothenburg-Hallsberg and Halmstad- Hässleholm;
- the Danish road link Kolding-Hirtshals/Frederikshavn of GreCOR is excluded from the CNC; and
- in addition to the direct Hamburg-Hannover link of GreCOR, the CNC includes also the connections Hamburg-Lauenbrück-Bremen, Bremen-Langwedel-Hannover, Lauenbrück-Visselhövede-Hannover and Langwedel-Visselhövede.

[3] About 60% of this figure concern exports of energy products (SITC 3) from Norway to the UK, which are not captured by LTM anyway.

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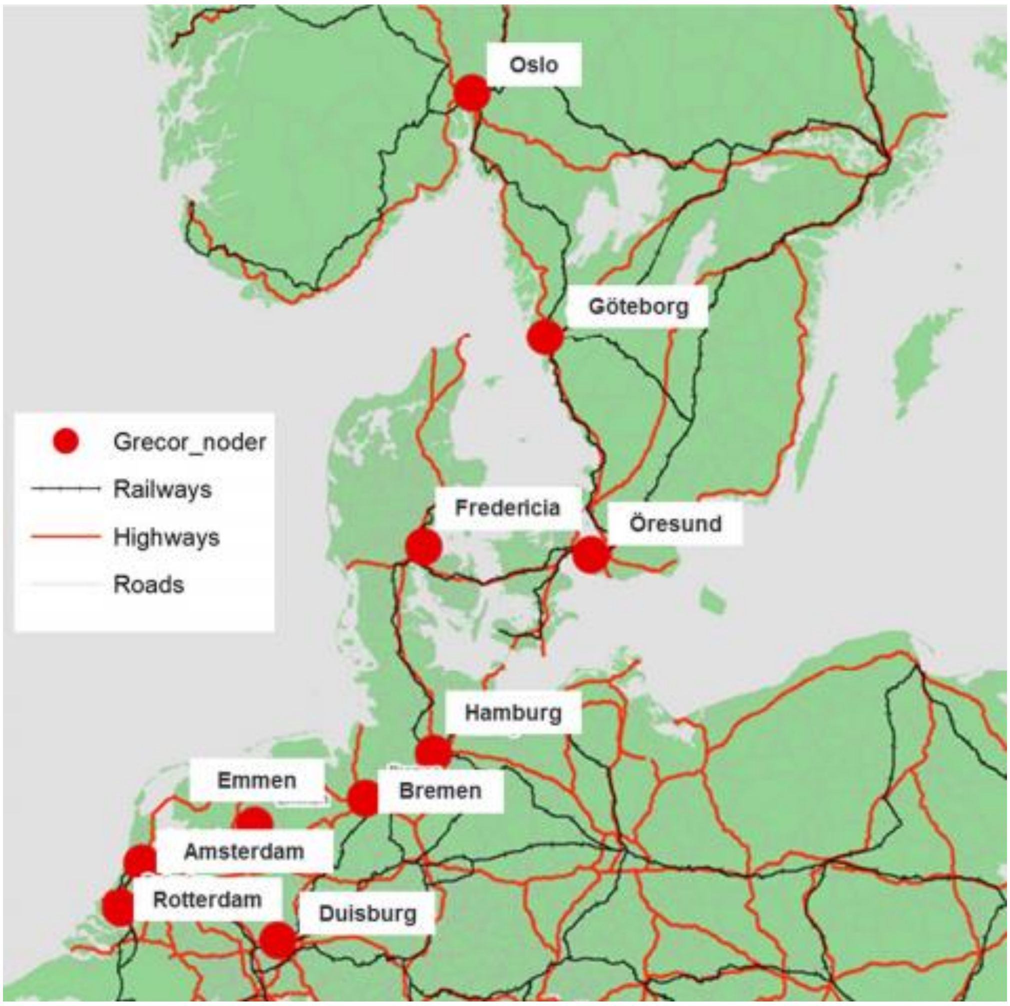

Figure 9. Nodes of Oslo-Randstad corridor. Source: GreCOR, 2012

As for the Hannover-Randstad part:

- The GreCOR road connection Hamburg – Amsterdam via Groningen (E22) is absent from the CNC;
- The CNC includes in addition the rail and road connections Hannover-Bremen-Bremerhaven/Wilhelmshaven; and
- The CNC also includes the rail and road connection Hannover-Köln-Antwerp.

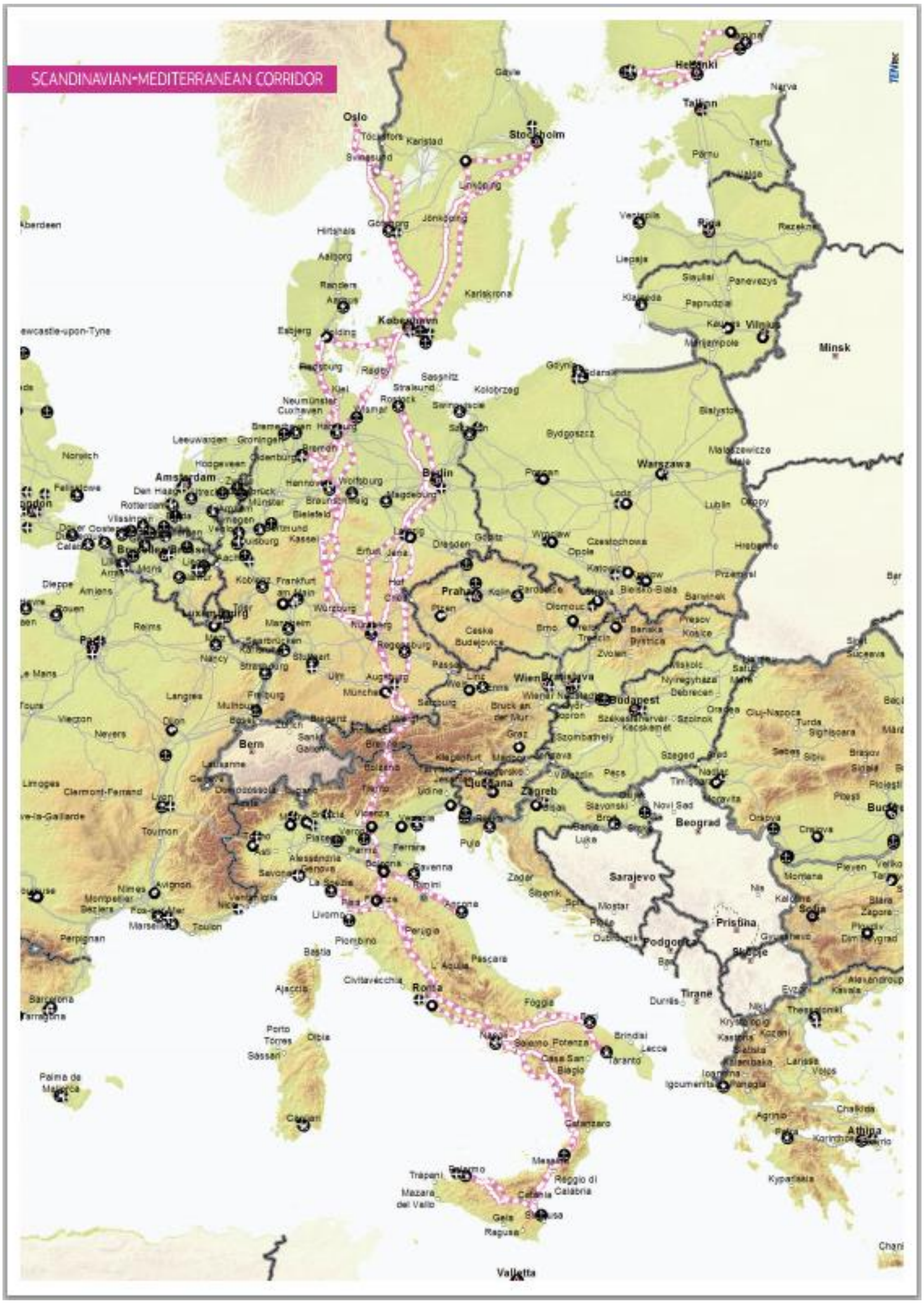

Figure 10. The ScanMed TEN-T core network corridor. Source: TENTec, 2015a

Figure 11. The North Sea - Baltic TEN-T core network corridor. Source: TENTec, 2015b

4.3 The GreCOR catchment area

Before incorporating the differences identified above into the GreCOR catchment area, it is worth checking one more source of information, the Scandinavian-Mediterranean Rail Freight Corridor. The preliminary routing of the Scandinavian part of this RFC, as appearing in the relevant draft Transport Market Study of November 2014 (ETC, 2014), is shown in Figure 12. Here, too, the Oslo-Hallsberg link is only mentioned as corridor-related line, while the direct Malmö-Halmstad link is defined as a diversionary route.

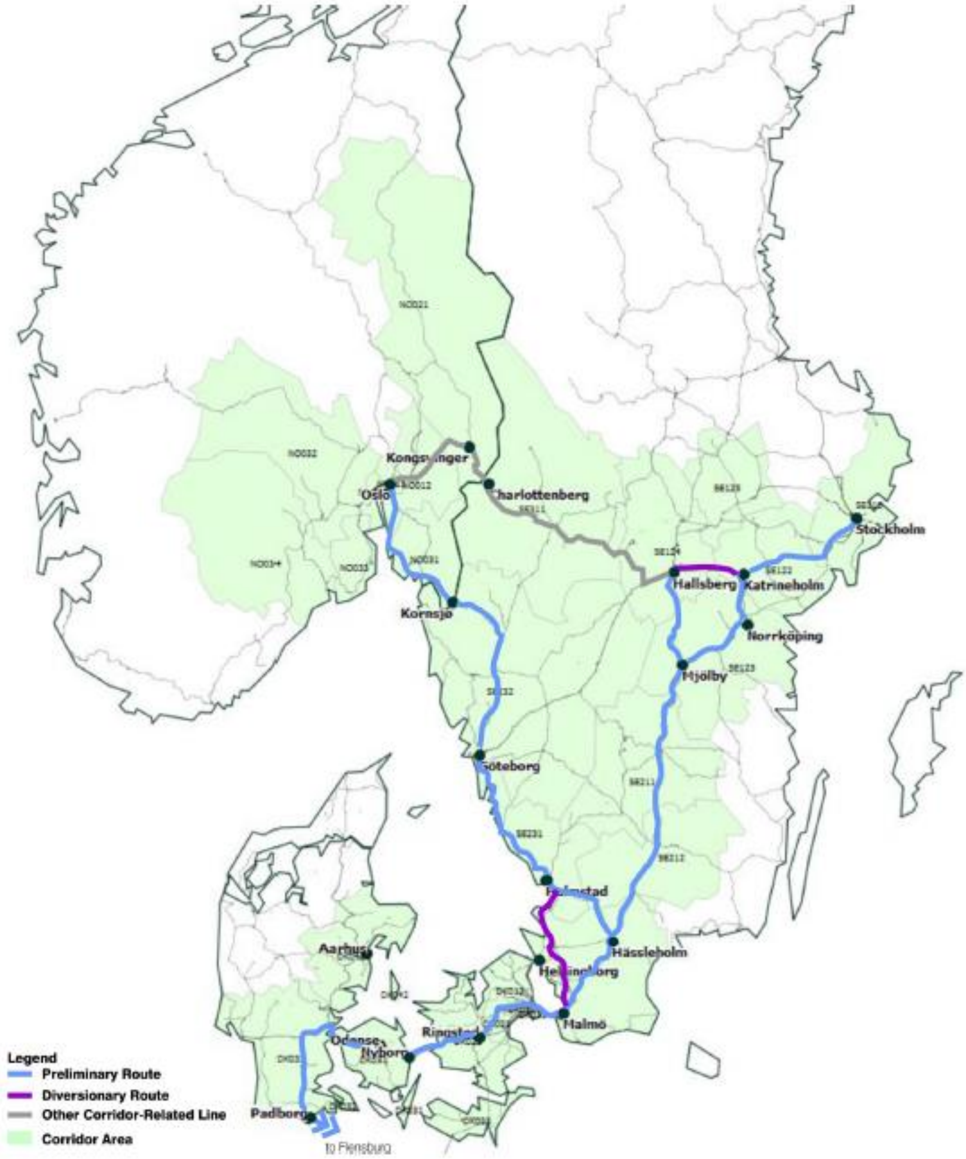

Figure 12. Catchment area and preliminary routing of ScanMed RFC in Scandinavia. Source: ETC, 2014

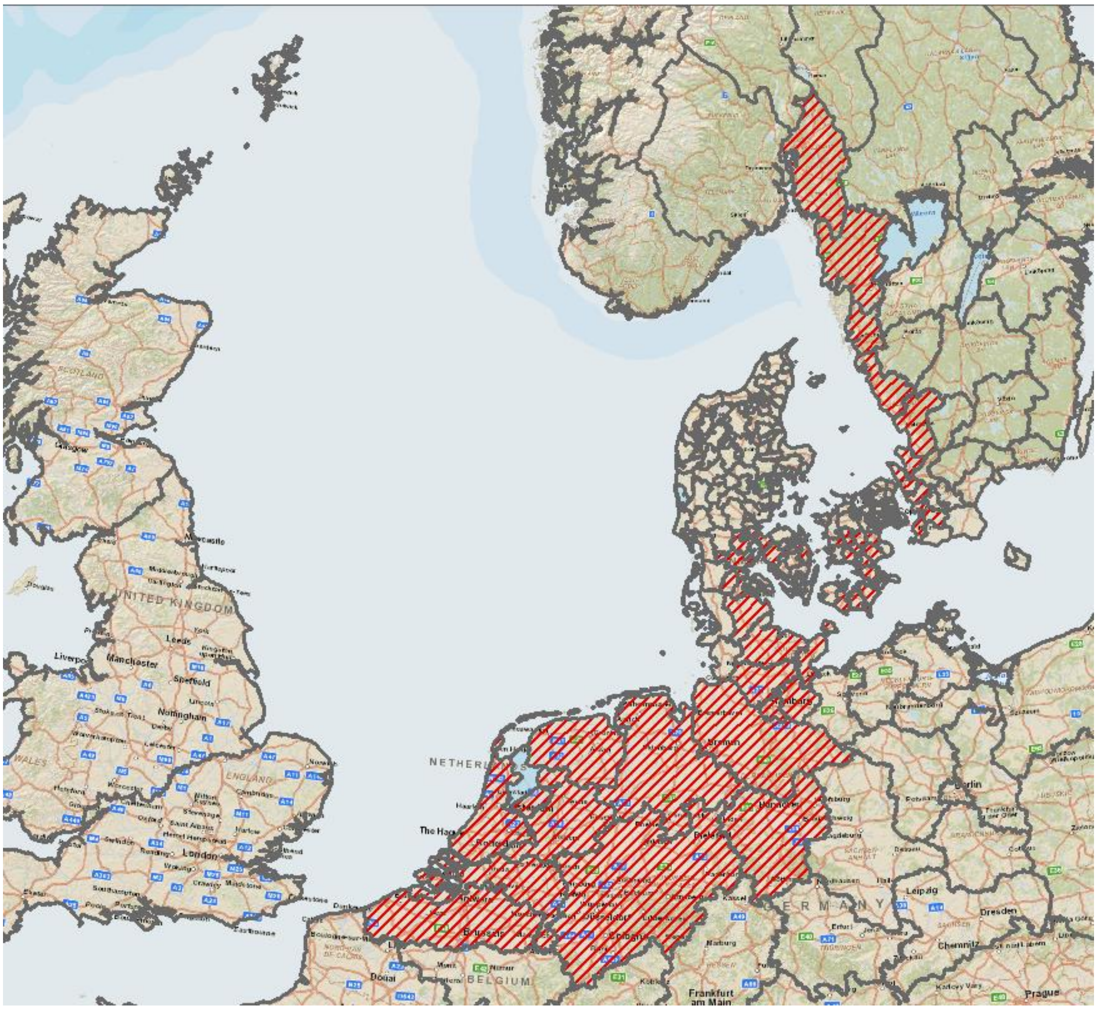

Figure 13. The GreCOR catchment area

When the GreCOR routes, modified to reflect the alignment of the Scan-Med and North Sea–Baltic CNCs, are introduced into the zonal system of LTM, the GreCOR catchment area of Figure 13 (marked in red) is produced. The disproportionate coverage of German, Dutch and Belgian regions in comparison to the Scandinavian areas is due to the much broader definition of LTM zones outside Scandinavia. In view of this fact, it was decided to maintain finally the E22 road connection Hamburg – Groningen – Amsterdam within the boundaries of the system, as it would be unrealistic and excessively restrictive to serve all this area by one east-west road axis.

It is worth mentioning, however, that the exclusion of a node from the catchment area does not preclude its use by a corridor chain. For example, this would allow Belgian cargoes to Oslo by rail to be routed via Hallsberg or Dutch cargoes to Copenhagen by ship to be routed via Esbjerg.

5. The selection of typical transport chains

The aim of this chapter is to present the construction of the sample of typical transport chains that will be used for assessing the performance of the GreCOR corridor. After describing the type of data that result from LTM, the boundaries of the analysis are set in an effort to reduce the size of the database into something more manageable. Then the criteria applied for constructing the sample are presented and the method is described through an example pertaining to a specific commodity group. The chapter concludes with the display of the complete sample.

5.1 Structure and composition of model results

As mentioned in Section 3.3, LTM produces three types of freight flows: (i) between the producer (P) and consumer (C) in the so-called PC-matrix, (ii) the above PC flows broken down into combinations of up to three OD (origin-destination) legs in the so-called chain matrix, and (iii) the separate OD legs in the so-called OD-matrix.

Table 5. Fields of the chain matrix database

General	Commodity	Commodity code as in Table 6
	Production zone	Code of P zone as in Figure 5
	Consumption zone	Code of C zone as in Figure 5
	Annual volume	Annual cargo flow in tonnes
	Chain type	25 types of up to 3 legs as in Table 8
	Containerisation	Yes/no
Leg 1	To zone	Zonal code as in Figure 5
	To terminal	354 terminals in DK and 660 abroad
	Mode	Road, rail, sea and Ro-Ro
	Consolidation	Yes/no (incl. deconsolidation)
	Vehicle type	8 types of trucks, 3 types of train, a conventional ship, a containership and a Ro-Ro ship
	No of vehicles	Needed to carry the annual flow
Leg 2	To zone	As in Leg 1
	To terminal	
	Mode	
	Consolidation	
	Vehicle type	
	No of vehicles	
Leg 3	To zone	As in Leg 1
	To terminal	
	Mode	
	Consolidation	
	Vehicle type	
	No of vehicles	

Although at first sight the OD-matrix appears as the most appropriate option for the application at hand, it turns out that it cannot be used because the output for a specific OD pair contains only flows between these exact origin (O) and destination (D) points, either on single- or multiple-leg voyages, but excludes flows that use this particular link as part of a longer leg. For example, the Malmö-Copenhagen rail link does not include the road-rail-road flows involving Gothenburg-Kolding as the middle rail leg despite them crossing the Øresund Bridge.

The chain matrix, consisting of PC chains broken down to OD legs, is the model output type best suited for corridor benchmarking. The results used in this application are those of Year 2010, which is the latest base (model calibration) year. Each entry of the chain matrix database corresponds to a transport chain. Table 5 shows the information provided for each chain in the form of separate fields.

The composition of the chain matrix by commodity appears in Table 6, together with the corresponding cargo volumes and number of chains. The database contains more than 2.9 million chains that conveyed almost 507 million tonnes in 2010. As expected, the energy products (codes 21 and 7 are the most

Table 6. Composition of chain matrix by commodity

ID	Commodity	Annual tonnes	No of chains
1	Products of agriculture, hunting, and forestry; fish and other fishing products	40.574.668	245.831
2	Coal and lignite	19.571.829	7.646
3	Iron ores and non-ferrous metal ores	13.199.566	76.006
4	Food products, beverages and tobacco	30.190.571	236.557
5	Textiles and textile products; leather and leather products	3.650.520	200.150
6	Wood and products of wood and cork (except furniture)	45.488.712	223.744
7	Coke and refined petroleum products	62.995.960	27.862
8	Chemicals , chemicals products, and man-made fibres; rubber and plastic products	36.868.486	184.906
9	Other non-metallic mineral products	15.560.549	203.555
10	Basic metals, fabricated metal products, except machinery and equipment	23.458.563	215.847
11	Machinery and equipment	18.305.567	156.526
12	Transport equipment	4.744.573	125.491
13	Furniture; other manufactured goods	19.993.166	233.532
14	Secondary raw materials; municipal wastes and other wastes	11.924.412	194.735
15	Mail, parcels	6.759.979	176.535
16	Equipment and material utilized in the transport of goods	249.571	16.093
17	Goods moved in the course of household and office removals	1.050.634	74.221
18	Grouped goods	2.862.862	99.080
19	Unidentifiable goods	0	0
20	Other goods	0	0
21	Crude petroleum and natural gas	99.275.548	7.945
22	Fertilizer, chemical and natural	8.581.166	95.220
23	Stone, sand, gravel, clay, peat and other mining and quarry products	41.382.172	133.235
	TOTAL	**506.689.075**	**2.934.717**

voluminous cargoes followed by wood, quarry and agricultural products. Commodities 19 (“unidentifiable goods”) and 20 (“other goods”) have no entries in the database and will not be recorded in the remaining of this report. The composition of the matrix by chain type appears in Table 8.

5.2 Boundaries of the analysis

Before analysing the matrix to select the sample chains, we set boundaries on the analysis that either reduce the size of the database or exclude irrelevant entries.

The first limit relates to the annual volumes of the cargo flows. A closer look at the records reveals a considerable number of chains with annual volumes very close to zero. Apparently this is due to the rounding specifications of the model (or lack of). In fact, as shown in Figure 14, about 60% of the entries concern chains with annual volumes below 1 tonne. The introduction of a threshold in the annual volumes of freight flowing through the network can, therefore, have a dramatic effect on the size of the database.

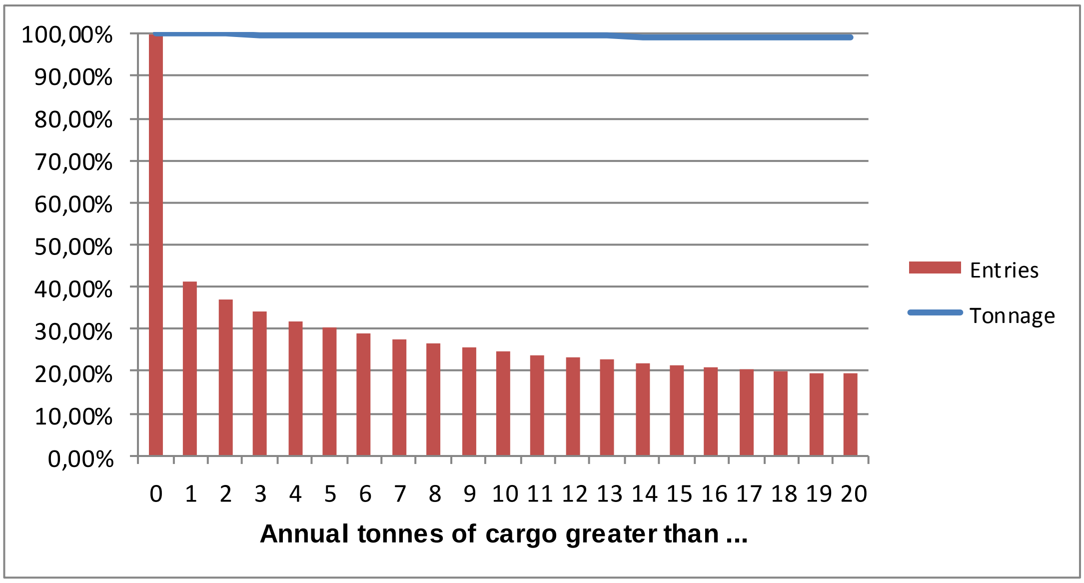

Figure 14. Effect of a minimum cargo volume on the number of chains

In setting the minimum acceptable level, Figure 14 shows that a limit of 20 tonnes per year would reduce the number of chains by more than 80%, while the sacrifice in terms of total tonnage would be less than 1%. Nevertheless, it was decided to minimise the effect of this intervention by setting the minimum acceptable volume of annual flows at 1 tonne. As shown in Table 7. Composition of the bounded chain matrix by commodity, this limits the number of chains to 1.2 million, while the rounded total tonnage is still 507 million tonnes.

The second intervention relates to border crossing. Green corridors are by definition international. Actually, both TEN-T core network corridors of Section 4.2 cross up to six borders in their full length. Aiming, once again, to a minimal intervention impact, we have set the limit to at least one border crossing. The number of chains has now dropped to 635 thousand (47% reduction in relation to the latest size) and the total volume now sums to 396 million tonnes, reflecting a 22% drop.

The last restriction to be imposed concerns the relation of the chains examined to the catchment area of the corridor. So far, the matrix contains chains of the following types:

- Totally irrelevant to GreCOR, e.g. Helsinki-Kaliningrad by ship;
- Originating <u>and</u> ending outside the catchment area of GreCOR but touching the corridor, e.g. Aalborg-Vienna by truck;
- Originating <u>or</u> ending within the GreCOR catchment area, e.g. Kolding-Verona by train, and
- Originating <u>and</u> ending within the GreCOR catchment area, e.g. Gothenburg-Ghent by Ro-Ro ship.

With the exception of the first category, all other types of chains have a bearing on the performance of the corridor, the extent of which depends on the actual overlap of the specific route with the corridor network. In order to exclude the possibility of external distortions, it was decided to restrict the analysis to the so-called "corridor" chains originating <u>and</u> ending within the GreCOR catchment area. The term "corridor chain" is borrowed from the Transport Market Study of the Scan-Med RFC, which follows exactly the same approach (ETC, 2014).

As shown in Table 7, this restriction results in 37,446 chains (5.9% of the international ones above 1 tonne) transporting 17.2 million tonnes (4.4% of the corresponding tonnage). Despite this dramatic fall, the resulting set of corridor chains is still sufficient to ensure a well-designed sample, covers all commodity groups and, according to Figure 15, the share of corridor chains in the international (> 1 tonne) ones fluctuates only from 3.5% (household and office removal goods) to 8.2% (equipment used in the transport of goods).

The composition of the chain matrix in relation to the chain type and its evolvement as we add boundaries to the analysis appears in Table 8. The original matrix contains chains of 25 different types featuring 1, 2 or 3 legs each.

There are five 1-leg chain types, all concerning road transport. The notations used are defined below:

Table 7. Composition of the bounded chain matrix by commodity

ID	Commodity	Original matrix		Above 1 tonne		Above 1 tonne, international		Above 1 tonne, international, within catchment area	
		Tonnes	Chains	Tonnes	Chains	Tonnes	Chains	Tonnes	Chains
1	Products of agriculture, fish, etc.	40.574.668	245.831	40.569.402	131.921	21.965.747	46.532	1.475.663	2.760
2	Coal and lignite	19.571.829	7.646	19.571.654	3.236	15.082.224	2.214	130.093	84
3	Iron ores and non-ferrous metal ores	13.199.566	76.006	13.194.263	19.704	12.233.947	17.951	336.673	1.339
4	Food products, beverages and tobacco	30.190.571	236.557	30.185.312	118.796	18.872.228	56.505	2.009.451	3.134
5	Textiles and leather products	3.650.520	200.150	3.634.408	73.099	2.948.109	51.744	270.242	3.096
6	Wood and products of wood and cork	45.488.712	223.744	45.478.652	94.332	40.099.948	50.883	1.466.753	2.811
7	Coke and refined petroleum products	62.995.960	27.862	62.994.754	12.310	60.271.690	8.958	3.449.555	486
8	Chemicals , chemicals products, etc.	36.868.486	184.906	36.862.048	65.228	35.201.808	46.326	2.596.137	2.751
9	Other non-metallic mineral products	15.560.549	203.555	15.553.000	86.924	9.900.957	45.671	789.124	2.616
10	Basic metals, fabricated metal products	23.458.563	215.847	23.442.763	100.577	19.957.412	63.004	1.034.014	3.501
11	Machinery and equipment	18.305.567	156.526	18.294.717	56.626	15.361.629	22.156	130.175	964
12	Transport equipment	4.744.573	125.491	4.734.996	35.992	3.139.391	14.976	323.634	815
13	Furniture; other manufactured goods	19.993.166	233.532	19.979.889	124.683	7.430.144	55.917	373.480	3.114
14	Secondary raw materials and other wastes	11.924.412	194.735	11.909.501	72.244	7.215.326	37.239	526.522	2.454
15	Mail, parcels	6.759.979	176.535	6.751.967	48.803	2.640.449	29.505	376.253	2.077
16	Equipment utilized in the transport of goods	249.571	16.093	249.127	1.540	208.617	1.508	26.621	123
17	Household and office removal goods	1.050.634	74.221	1.045.215	17.291	148.210	1.688	891	59
18	Grouped goods	2.862.862	99.080	2.859.437	28.761	2.859.437	28.761	392.971	2.198
21	Crude petroleum and natural gas	99.275.548	7.945	99.275.156	2.218	96.842.478	1.940	1.201.714	101
22	Fertilizer, chemical and natural	8.581.166	95.220	8.577.462	51.940	7.084.394	20.776	53.964	1.116
23	Stone, sand, gravel and other quarry products	41.382.172	133.235	41.375.824	61.801	16.528.246	30.431	273.223	1.847
	TOTAL	**506.689.075**	**2.934.717**	**506.539.547**	**1.208.026**	**395.992.391**	**634.685**	**17.237.155**	**37.446**

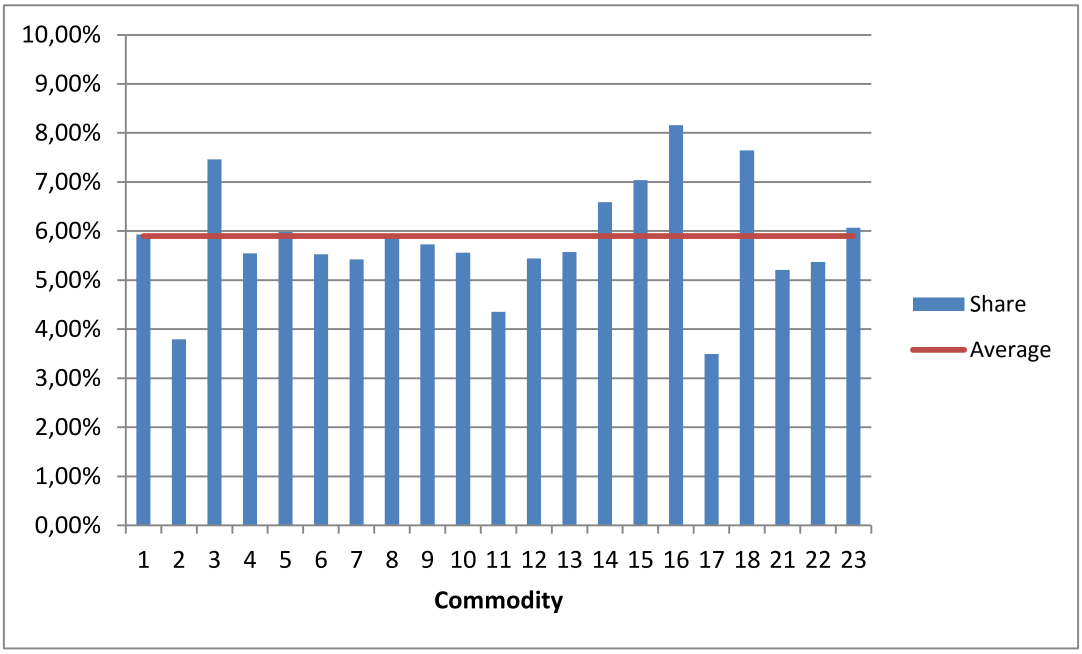

Figure 15. Corridor chains as percentage of international (> 1t) ones by commodity

- ”No crossing” refers to road chains connecting origins and destinations in Scandinavia, irrelevant to a future Fehmarn Belt fixed link.
- “Land border” refers to road chains crossing the land border between Denmark and Germany.
- “Ferry” refers to road chains connecting Denmark to locations south of the Fehmarn Belt, which involve the use of a ferry.
- “Transit DK” refers to road chains between origins/ destinations outside Denmark that cross the country in transit.
- “Direct ferry” refers to road chains between origins/destinations outside Denmark that use a direct Ro-Ro connection bypassing DK.

Twelve chain types consist of 2 legs. Eight of them are all-road chains involving the last four of the types listed above in combination with a first- or last-mile feeder service. Two types (17 and 71) entail road / rail combinations, while the other two (18 and 81) concern truck / ship arrangements.

The remaining 8 types relate to 3-leg chains, where the first and third legs are always road feeder services. The middle leg can be either one of the 5 road types listed above or one of rail, conventional ship and Ro-Ro ship.

Table 8. Composition of the bounded chain matrix by chain type

		Original matrix		Above 1 tonne		Above 1 tonne, international		Above 1 tonne, international, within catchment area	
ID	Chain description	Tonnes	Chains	Tonnes	Chains	Tonnes	Chains	Tonnes	Chains
1	1 leg; road "no crossing"	77.049.239	156.432	77.048.906	153.978	3.659.403	8.563	440.012	686
2	1 leg; road "land border"	12.336.046	93.676	12.334.775	51.061	11.066.278	44.633	1.449.818	3.382
3	1 leg; road "ferry"	2.700.090	85.713	2.699.135	44.665	2.410.150	38.590	310.607	2.804
5	1 leg; road "transit DK"	2.524.837	18.789	2.524.507	4.276	1.806.875	3.654	147.215	238
6	1 leg; road "direct ferry"	10.937.275	15.261	10.936.984	4.149	10.646.958	3.603	47.656	216
12	2 legs; road | road "land border"	422.810	33.229	419.285	19.452	-	-	-	-
13	2 legs; road | road "ferry"	242.994	34.307	239.405	18.789	-	-	-	-
15	2 legs; road | road "transit DK"	812.409	10.537	811.513	6.229	-	-	-	-
16	2 legs; road | road "direct ferry"	449.233	11.400	448.266	5.857	-	-	-	-
17	2 legs; road | rail	340.604	42.918	340.256	1.275	-	-	-	-
18	2 legs; road | conventional ship	5.753.571	58.496	5.753.038	2.734	-	-	-	-
21	2 legs; road "land border" | road	162.229	29.587	158.331	13.961	-	-	-	-
31	2 legs; road "ferry" | road	116.855	30.439	112.825	13.125	-	-	-	-
51	2 legs; road "transit DK" | road	411	9.460	98	60	-	-	-	-
61	2 legs; road "direct ferry" | road	283	10.560	39	27	-	-	-	-
71	2 legs; rail | road	404.927	41.591	403.308	4.603	-	-	-	-
81	2 legs; conventional ship | road	3.975.768	54.931	3.973.852	7.963	-	-	-	-
111	3 legs; road | road "no crossing" | road	15.503.146	505.279	15.465.320	343.945	1.861.023	27.075	224.907	671
121	3 legs; road | road "land border" | road	5.409.821	269.572	5.387.617	163.062	5.387.617	163.062	441.072	9.061
131	3 legs; road | road "ferry" | road	3.010.722	275.534	2.985.584	158.025	2.985.584	158.025	296.666	9.300
151	3 legs; road | road "transit DK" | road	1.677.370	29.926	1.675.323	9.347	1.675.323	9.347	135.625	427
161	3 legs; road | road "direct ferry" | road	2.303.137	31.514	2.301.278	9.631	2.301.278	9.631	70.814	418
171	3 legs; road | rail | road	21.310.226	387.329	21.302.495	32.845	20.473.429	31.784	416.509	1.614
181	3 legs; road | conventional ship | road	322.537.375	394.142	322.526.922	53.627	315.033.466	51.379	12.103.423	2.530
191	3 legs; road | Ro-Ro | road	16.707.697	304.095	16.690.484	85.340	16.685.008	85.339	1.152.831	6.099
	TOTAL	**506.689.075**	**2.934.717**	**506.539.547**	**1.208.026**	**395.992.391**	**634.685**	**17.237.155**	**37.446**

A fact that draws immediate attention is the absence of 2-leg chains from the international matrix. Apparently this relates to the design of the model, as it is hard to find a good explanation for the complete lack of 2-leg chains in international trades, especially when it comes to short-distance routes in the border areas. However, judging on the share of the 2-leg chains in the original matrix, it seems that this is of limited importance.

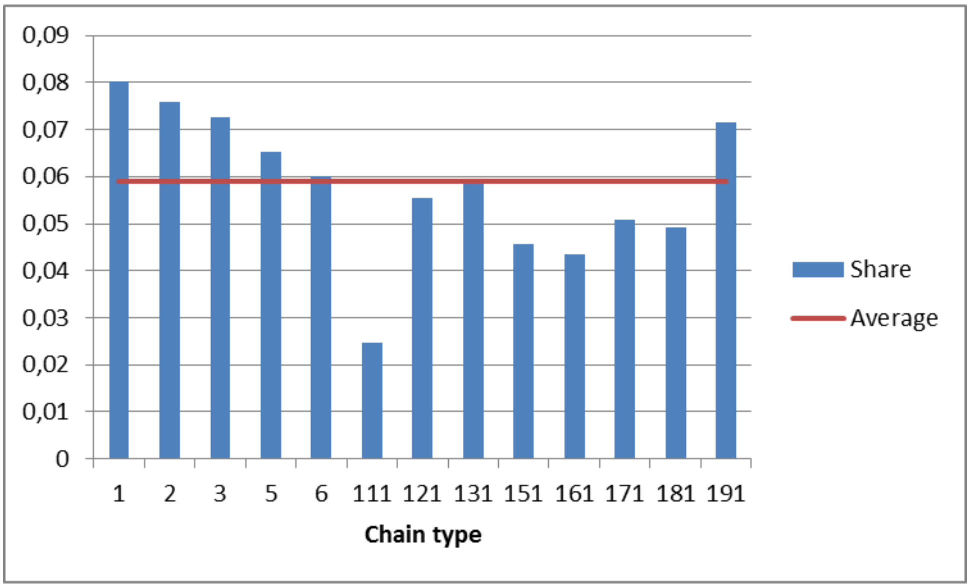

Figure 16. Corridor chains as percentage of international (> 1t) ones by chain type

As for restricting the analysis to the corridor chains, Figure 16 shows that there are no big surprises in the behaviour of the chain types. An interesting observation relates to the fact that although Type 1 (1-leg, "no crossing" road) exhibits the highest above average share, the corresponding Type 111 (3-leg, "no crossing" road with feeder services before and after) displays the lowest below average score. In fact, the same applies to all other road types at a lesser extent. This is a proof that the design of the GreCOR catchment area (Figure 13) has succeeded in capturing the core services of the corridor, placing less emphasis on the feeder services from/to more remote areas.

5.3 Sampling criteria and method

The method developed for this application takes advantage of basically all available information as provided by LTM (refer to Table 5). The commodity, chain type, containerisation and annual volume attributes are of particular importance in selecting the sample chains, while the production/consumption zone and vehicle type information also play a role. In addition, annual volumes are used for weights in aggregating KPIs into higher level indicators.

As shown in Figure 17, the sample has four levels of aggregation. The corridor (Level 1) consists of commodity groups (Level 2), as it this attribute that basically defines the modes, chain types and vehicles used. Commodity groups are further decomposed into sub-groups on the basis of chain type (Level 3). These sub-groups comprise of individual chains (Level 4), which are the equivalent of 'elementary aggregates' in the CPI terminology.

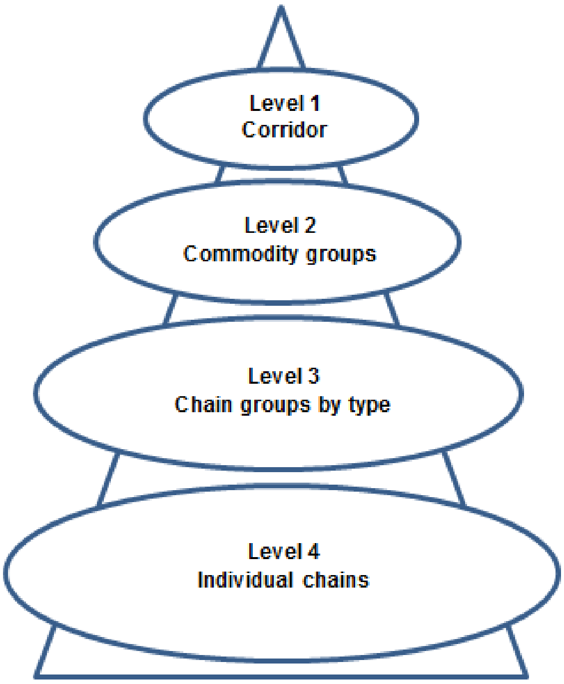

Figure 17. Sample structure

In defining the commodity groups, attention is paid to the special requirements that cargoes impose on all aspects of transport operations including the mode, vehicle types, loading units, handling equipment and facilities, business models, and even speed, ambient conditions, safety precautions, etc. Taking into consideration such requirements, the commodity groups of Table 7 have been rearranged as follows:

- **Com.1; Agricultural products, fish, etc.:** It is kept separate due to the perishable nature of these cargoes. In fact, it is broken down into two commodity groups; Group 1A involving containers (most probably refrigerated ones) and Group 1B for non-containerised cargoes, which still need to be treated with extra care due to their sensitivity.

- **Com.2; Coal and lignite:** It is kept separate as it is moved in bulk requiring special vehicles and (un)loading facilities. Tramp shipping is the most common arrangement for waterborne transport.
- **Com.3; Iron ore and non-ferrous metal ores:** It is kept separate as it is moved in bulk requiring special vehicles and (un)loading facilities. Tramp shipping is the norm for maritime operations. It is much denser than coal (5.1 vs. 1.5 t/cu.m)[4].
- **Com.6; Wood and products:** It is divided in two parts. Non-containerised wood and wood products are kept as a separate commodity group as they require special handling equipment and facilities. Containerised wood and products are included in the group Rest_A, together with all other commodities using dry containers.
- **Com.7; Coke and petroleum products:** It is kept separate as it is usually transported in large quantities requiring special product carriers.
- **Com.14; Secondary raw material and wastes:** It is kept separate as it requires special handling equipment and cannot be mixed easily with other cargoes.
- **Com.15; Mail and parcels:** It is kept separate because of special business arrangements (owned fleets and facilities in most cases).
- **Com.21; Crude oil and natural gas:** It is kept separate as it is usually transported in large quantities requiring special crude oil or LNG tankers.
- **Com.22; Fertilizers:** It is kept separate because it is transported either in bulk or in sacks that are not mixed with other commodities.
- **Com.23; Stone, sand, gravel and quarry products:** It is kept separate as it is moved in bulk. Its density (1.4–2.8 t/cu.m) is between these of coal and iron ore.
- **All other commodities (Com.4, 5, 8, 9, 10, 11, 12, 13, 16, 17, and 18):** Generally, these are cargoes that can be mixed in the same vehicle. They are grouped together and divided into two commodity groups; Group Rest_A involving containers and Group Rest_B concerning non-containerised cargoes.

[4] http://www.engineeringtoolbox.com/density-solids-d_1265.html

As a next step, each one of the above commodity groups have to be decomposed into sub-groups by chain type. Commodity group 22 (fertilizers) will be used here as an example. The 1,116 chains of Table 7 for this commodity are broken down by chain type in Table 9. In addition to the five 1-leg road connection types defined in Section 5.2 and the corresponding 3-leg arrangements involving first- and last-mile feeder services, trains (171) and ships (181) are employed in transporting fertilisers along the corridor.

Table 9. Sample design for Commodity group 22 (fertilizers)

CHAIN TYPE	MODEL RESULTS					SAMPLE		
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km
Commodity group 22: Fertilizers								
1	2.250	9	250	453	1.019.240			
2	18.462	100	185	502	9.275.328	1	21.259	10.889.129
3	3.515	82	43	564	1.980.694	1	3.601	2.047.783
5	547	2	274	1.087	594.561			
6	86	1	86	780	67.088			
111	47	10	5	423	19.870			
121	7.335	422	17	664	4.867.086	4	8.904	6.321.915
131	4.539	428	11	633	2.874.265	4	5.971	3.600.961
151	1.522	12	127	943	1.434.959			
161	1.433	13	110	507	726.696			
171	4.642	16	290	982	4.556.469	1	4.642	4.556.469
181	9.588	21	457	684	6.555.747	1	9.588	6.555.747
TOTAL 22	53.964	1.116	48	630	33.972.003	12	53.964	33.972.003

How is the sample designed? As a general principle, the chains included in the sample should be selected carefully to represent the range of services acquired by the shippers in the vicinity of the corridor. In doing so, the following criteria should be taken into consideration:

- The importance of a particular chain type relative to the total traffic. In general, higher importance should be reflected in a larger number of chains in the sample.
- The degree of homogeneity in the range of services provided under a particular chain type. Higher homogeneity should lead to fewer sample chains.
- The degree to which the various services covered by a chain type are subject to different influences and pressures in relation to the KPIs that will be used in the analysis. Higher sensitivity differences require more chains in the sample.
- The likelihood that a particular service will continue to be available for a reasonable period of time. Unstable services should be avoided.

- The extent to which a service can be defined and described clearly and unambiguously to ensure constant quality of service over time. Inadequately defined services should be avoided.

In the present model-based application, only the first three of the above mentioned criteria matter. Judging the relative importance of a chain type can be based on either the tonnage or the number of chains the particular type contains. Given that the tonnage will be used as weight in aggregating chain-level indicators into higher-level KPIs, the design of the sample is based on the number of chains. In terms of homogeneity, rail and shipping services are generally more standardised than road haulage. As for differences in the effect of external factors, the composition of the vehicle fleet employed on a particular road transport chain can be considered.

Returning to the fertilizer example, the effort is to express the distribution of model chains among the various types with as few sample chains as possible. It is obvious that the fit depends on the number of chains to be selected. Having in mind a total sample in the order of 100 chains, we set a tentative target at about 10 chains per commodity group. In the fertilizer case, this would roughly mean selecting one chain per hundred. So, chain types 2 and 3 are represented in the sample with one chain each, while 4 chains are selected for each one of types 121 and 131.

Provided that the 10 first chain types of Table 9 (1 to 161) refer to road transport, the selection made so far would leave rail and maritime transport uncovered. Given that tonnage-wise both these types deserve to be represented in the sample, it was decided to add one additional chain in the sample for each of these two types. The comparison between the model and sample distribution of chains is schematically depicted in Figure 18.

Once the sample has been designed, the weights (annual tonnages and tonne*km) need to be adjusted to reflect this design. This is done through allocating the tonnage/tkm of types not represented in the sample to the most closely related chain types in the sample under the assumption that their corresponding KPI movements are similar.

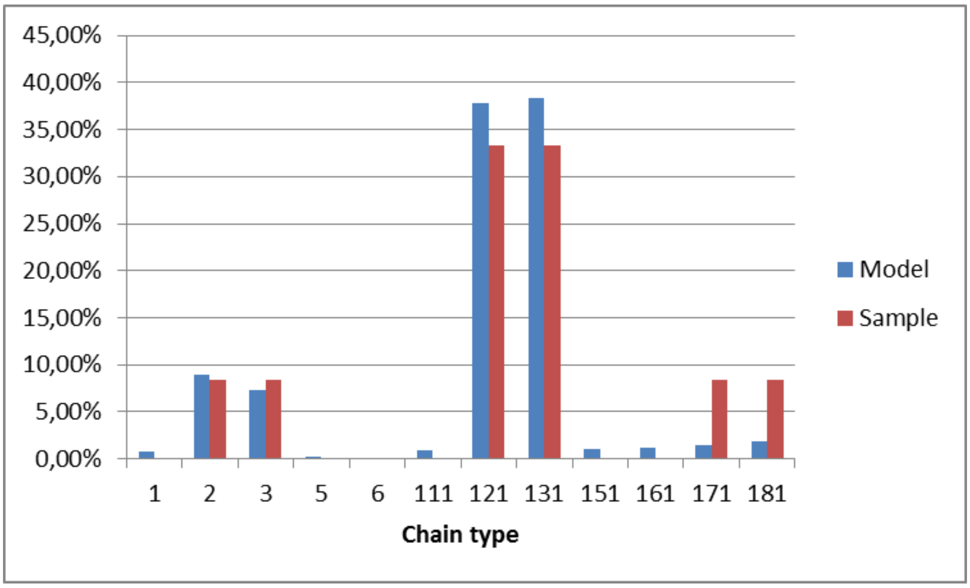

Figure 18. Model and sample distributions of chains for Commodity group 22 (fertilizers)

As such, the tonnes/tkm of Types 1 (“no crossing”) and 5 (“transit DK”) has been added to this of Type 2 (“land border”) as the distinction is basically geographic, while the Type 3 (“ferry”) tonnes/tkm have been increased by those of Type 6 (“direct ferry”). Similar adjustments have been made to the 3-leg road transport chains. The sample structure and the corresponding weights for all commodity groups are shown in Appendix I.

We are now ready to select the individual chains. Let’s start with Chain type 2 concerning 1-leg road voyages crossing the DK-DE land border. One chain has to be selected out of the 100 connections of Figure 19. The first criterion to be applied relates to the types of vehicles used in this trade. As shown in Table 10, 86 out of the 100 journeys involve articulated trucks, leaving no room for doubts as for the vehicle of the selected chain.

Table 10. Vehicle types involved in carrying fertilizers over the”land border”

Vehicle type	Annual tonnes	No of chains
Truck 3.5-12 tonnes	5	1
Truck 12 - 18 tonnes	45	3
Truck 18 - 26 tonnes	102	2
Truck with trailer 12-18 tonnes	228	7
Truck with trailer > 18 tonnes	179	1
Articulated truck	17.903	86
Total	**18.462**	**100**

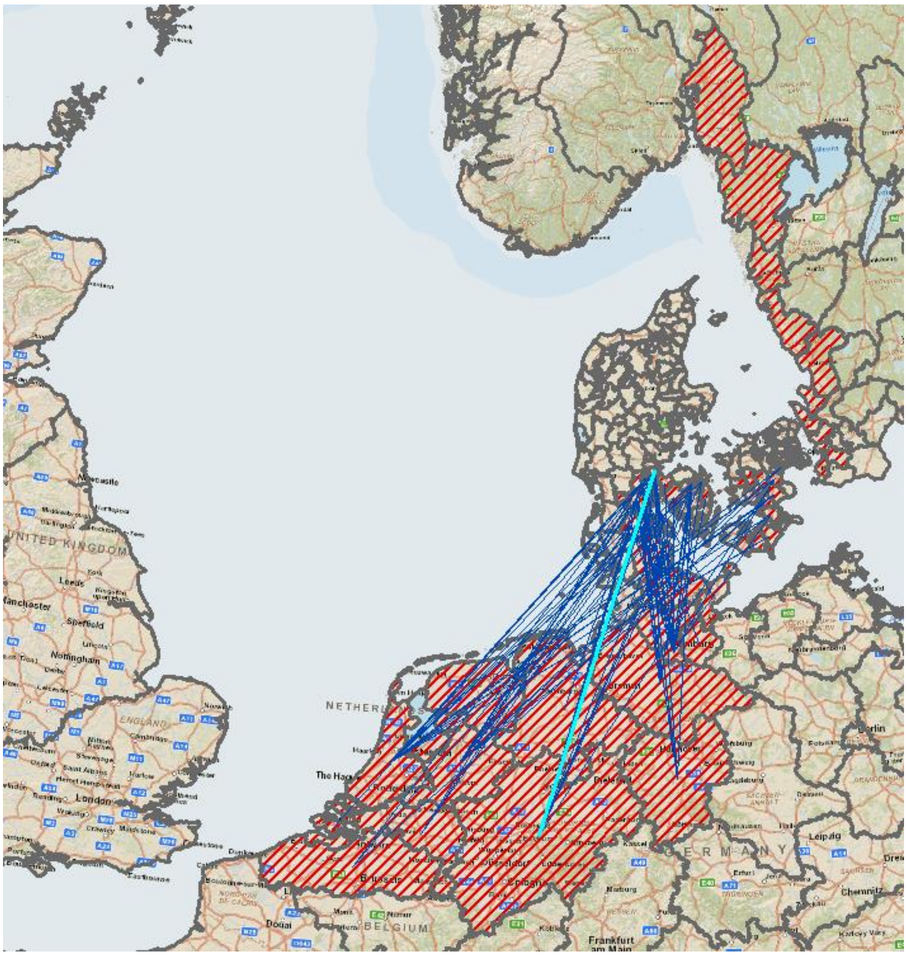

Figure 19. ”Land border” road chains of Commodity group 22 (fertilizers)

A number of criteria deriving from the LTM results can be applied for the selection. The following ones do not require extensive data manipulation effort:

- Origin with the highest number of connections: Utrecht (NL)
- Origin with the highest annual volume: Fredericia (DK)
- Destination with the highest number of connections: Kolding-rural (DK)
- Destination with the highest annual volume: Kolding-rural (DK)
- Connection with the highest annual volume: Fredericia (DK) – Borken (DE)
- Connection with an annual volume as close as possible to the average tonnes per chain of Table 9: Borken (DE) – Køge (DK).

In this case, the link with the highest tonnage, Fredericia-Borken, was selected (appears in Figure 19 in light blue).

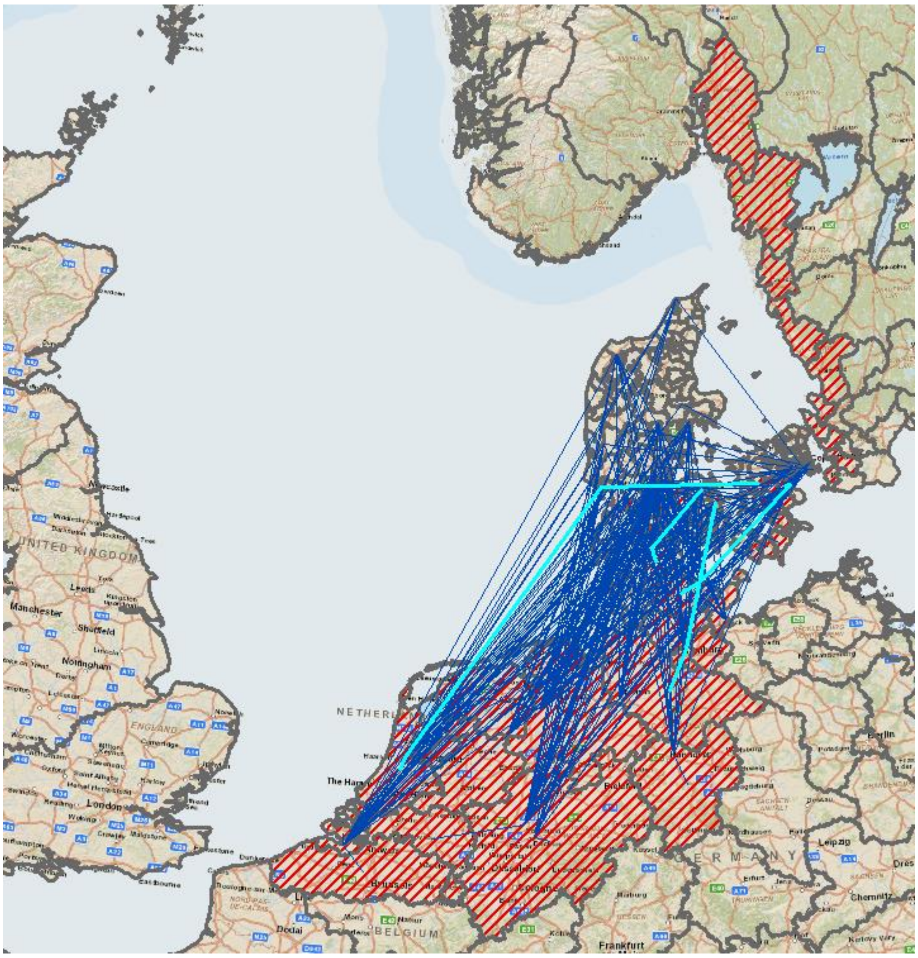

Figure 20. "Ferry" connections supplemented by feeder services for fertilizers

A more complicated example concerns Chain type 131, which combines a ferry-related middle leg with feeder services at both ends. Four chains need to be selected among the 428 of Figure 20.

Table 11. Vehicle types involved in the 3-leg"ferry" connections for fertilizers

	Leg 1		Leg 2		Leg 3	
Vehicle type	**Annual tonnes**	**No of chains**	**Annual tonnes**	**No of chains**	**Annual tonnes**	**No of chains**
Light goods vehicle	310	26	0	0	436	66
Truck 3.5-12 tonnes	289	56	0	0	243	44
Truck 12 - 18 tonnes	1.374	261	0	0	1.249	235
Truck 18 - 26 tonnes	305	8	0	0	373	10
Truck with trailer 12-18 tonnes	765	40	0	0	780	39
Truck with trailer > 18 tonnes	357	6	0	0	411	7
Articulated truck	1.137	31	4.539	428	1.045	27
Total	**4.539**	**428**	**4.539**	**428**	**4.539**	**428**

The composition of the fleets involved in all 3 legs is shown in Table 11. It is of no surprise that only articulated trucks are employed for the middle leg. In order to achieve the best possible representation, the selected chains should involve one 3.5-12t and three 12-18t trucks for Leg 1. Similarly, Leg 3 should be performed by one light truck, one 3.5-12t and two 12-18t vehicles.

The highest volume connections that fulfil these restrictions are the starting point for selecting the sample chains. The final set takes also into consideration the need to avoid selecting chains involving the same ferry link. The selected chains, marked in light blue in Figure 20, are listed in Table 12 together with all other GreCOR sample chains.

Table 12. The GreCOR sample chains

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	PRODUCTION ZONE	VEHICLE LEG 1	FIRST TERMINAL	VEHICLE LEG 2	SECOND TERMINAL	VEHICLE LEG 3	CONSUMPTION ZONE
Commodity group 1A: Agro products - Containerised									
1	191	351	Ghent (BE)	Articulated truck	Ghent (BE)	Ro-Ro ship	Tønsberg (NO)	Articulated truck	Akershus (NO)
2	191	86	Hamburg (DE)	Truck 18-26t	Lübeck (DE)	Ro-Ro ship	Helsingborg (SE)	Truck 18-26t	Valby (DK)
3	191	263	Zuidoost-Noord-Brabant (NL)	Articulated truck	Antwerp (BE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Uddevalla (SE)
4	191	248	Utrecht (NL)	Articulated truck	Amsterdam (NL)	Ro-Ro ship	Esbjerg (DK)	Articulated truck	Fredericia (DK)
5	191	183	Hamburg (DE)	Articulated truck	Hamburg (DE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Uddevalla (SE)
Commodity group 1B: Agro products - Non-containerised									
6	2	239	Assens (DK)			Articulated truck			Rotenburg (Wumme) (DE)
7	3	57	Faxe (DK)			Articulated truck			Borken (DE)
8	121	36	Greve (DK)	Truck 18-26t	Tønder (DK)	Articulated truck	Bremen (DE)	Truck 18-26t	Cloppenburg (DE)
9	121	211	Overig Groningen (NL)	Articulated truck	Dörpen (DE)	Articulated truck	Silkeborg (DK)	Articulated truck	Fredericia (DK)
10	121	7	Veluwe (NL)	Truck 12-18t	Coevorden (NL)	Articulated truck	Esbjerg (DK)	Truck 12-18t	Næstved NV (DK)
11	131	25	Kastrup Lufthavn (DK)	Light truck	Køge (DK)	Articulated truck	Hannover-Linden (DE)	Truck/trailer 12-18t	Hannover (DE)
12	131	29	Køge (DK)	Truck 18-26t	Køge (DK)	Articulated truck	Hamburg (DE)	Truck 18-26t	Segeberg (DE)
13	131	39	Ringsted (DK)	Truck 18-26t	Esbjerg (DK)	Articulated truck	Terneuzen (NL)	Truck 18-26t	Overig Zeeland (NL)
14	171	820	Svalöv (SE)	Articulated truck	Helsingborg (SE)	Conventional train	Antwerp (BE)	Articulated truck	Ghent (BE)
15	181	4668	Herzogtum Lauenburg (DE)	Articulated truck	Hamburg (DE)	Conventional ship	Oslo (NO)	Articulated truck	Akershus (NO)
Commodity group 2: Coal & lignite									
16	2	6243	Padborg (DK)			Articulated truck			Rotenburg (Wumme) (DE)
17	5	180	Uddevalla (SE)			Articulated truck			Utrecht (NL)
18	6	70	Uddevalla (SE)			Articulated truck			Zuidoost-Noord-Brabant (NL)
19	171	23	Zuidoost-Noord-Brabant (NL)	Articulated truck	Genk (BE)	Conventional train	Oslo (NO)	Articulated truck	Akershus (NO)
20	181	3627	Utrecht (NL)	Articulated truck	Amsterdam (NL)	Conventional ship	Kolding Havn (DK)	Articulated truck	Kolding city (DK)
Commodity group 3: Iron ore & non-ferrous metal ores									
21	2	242	Hamburg (DE)			Articulated truck			Assens (DK)
22	2	55	Rendsburg-Eckernforde (DE)			Articulated truck			Padborg (DK)
23	3	29	Hamburg (DE)			Articulated truck			Middelfart (DK)
24	3	18	Rotenburg (Wumme) (DE)			Articulated truck			Falster (DK)
25	121	15	Ghent (BE)	Articulated truck	Terneuzen (NL)	Articulated truck	Copenhagen (DK)	Articulated truck	Vesterbro (DK)
26	121	10	Slagelse (DK)	Truck 12-18t	Fredericia (DK)	Articulated truck	Marl (DE)	Truck 12-18t	Zuidoost-Noord-Brabant (NL)
27	121	15	Glostrup (DK)	Light truck	Herning (DK)	Articulated truck	Coevorden (NL)	Truck 18-26t	Veluwe (NL)
28	121	23	Brøndby (DK)	Light truck	Køge (DK)	Articulated truck	Dörpen (DE)	Truck 18-26t	Overig Groningen (NL)
29	131	4	Hamburg (DE)	Truck 18-26t	Hamburg (DE)	Articulated truck	Rødby Havn (DK)	Truck 18-26t	Midtlolland (DK)
30	131	11	Rotenburg (Wumme) (DE)	Truck/trailer > 18t	Hamburg (DE)	Articulated truck	Copenhagen (DK)	Light truck	Vesterbro (DK)
31	131	6	Midtlolland (DK)	Truck 12-18t	Rødby Havn (DK)	Articulated truck	Terneuzen (NL)	Truck 12-18t	Ghent (BE)
32	131	24	Køge (DK)	Truck/trailer > 18t	Køge (DK)	Articulated truck	Terneuzen (NL)	Truck/trailer > 18t	Overig Zeeland (NL)
33	171	871	Borken (DE)	Articulated truck	Duisburg (DE)	Conventional train	Padborg (DK)	Articulated truck	Padborg (DK)
34	181	2627	Køge (DK)	Articulated truck	Køge Havn (DK)	Conventional ship	Bremen (DE)	Articulated truck	Borken (DE)

Table 12. The GreCOR sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	PRODUCTION ZONE	VEHICLE LEG 1	FIRST TERMINAL	VEHICLE LEG 2	SECOND TERMINAL	VEHICLE LEG 3	CONSUMPTION ZONE
Commodity group 6: Wood products - Non-containerised									
35	2	1985	Hamburg (DE)			Articulated truck			Kolding rural (DK)
36	2	589	Rotenburg (Wumme) (DE)			Articulated truck			Assens (DK)
37	2	220	Veluwe (NL)			Articulated truck			Haderslev (DK)
38	3	222	Køge (DK)			Articulated truck			Ostholstein (DE)
39	3	152	Lolland Øst (DK)			Articulated truck			Rendsburg-Eckernforde (DE)
40	121	229	Zuidoost-Noord-Brabant (NL)	Articulated truck	Marl (DE)	Articulated truck	Silkeborg (DK)	Articulated truck	Middelfart (DK)
41	121	24	Nyborg (DK)	Truck/trailer > 18t	Odense (DK)	Articulated truck	Hannover-Linden (DE)	Truck/trailer > 18t	Hannover (DE)
42	131	46	Midtlolland (DK)	Articulated truck	Rødby Havn (DK)	Articulated truck	Marl (DE)	Articulated truck	Zuidoost-Noord-Brabant (NL)
43	131	30	Ghent (BE)	Articulated truck	Terneuzen (NL)	Articulated truck	Esbjerg (DK)	Light truck	Slagelse (DK)
44	171	2498	Malmö (SE)	Articulated truck	Malmö (SE)	Conventional train	Duisburg (DE)	Articulated truck	Borken (DE)
45	181	208000	Halmstad (SE)	Articulated truck	Halmstad (SE)	Conventional ship	Bremen (DE)	Articulated truck	Borken (DE)
46	181	78381	Akershus (NO)	Articulated truck	Oslo (NO)	Conventional ship	Antwerp (BE)	Articulated truck	Ghent (BE)
47	181	15500	Uddevalla (SE)	Articulated truck	Uddevalla (SE)	Conventional ship	Antwerp (BE)	Articulated truck	Zuidoost-Noord-Brabant (NL)
Commodity group 7: Coke & petroleum products									
48	1	567	Akershus (NO)			Articulated truck			Køge (DK)
49	2	465	Hamburg (DE)			Articulated truck			Padborg (DK)
50	3	112	Hannover (DE)			Articulated truck			Brøndby (DK)
51	5	158	Akershus (NO)			Articulated truck			Overig Zeeland (NL)
52	111	630	Kolding city (DK)	Articulated truck	Kolding (DK)	Articulated truck	Drammen (NO)	Articulated truck	Akershus (NO)
53	121	23	Zuidoost-Noord-Brabant (NL)	Articulated truck	Marl (DE)	Articulated truck	Brørup (DK)	Light truck	Brøndby (DK)
54	131	21	Fredericia (DK)	Truck/trailer 12-18t	Fredericia Havn (DK)	Articulated truck	Lübeck (DE)	Truck/trailer 12-18t	Ostholstein (DE)
55	151	25	Akershus (NO)	Truck/trailer 12-18t	Munkedal (SE)	Articulated truck	Bremen (DE)	Truck/trailer 12-18t	Cloppenburg (DE)
56	161	205	Akershus (NO)	Articulated truck	Drammen (NO)	Articulated truck	Terneuzen (NL)	Articulated truck	Ghent (BE)
57	171	273	Hannover (DE)	Articulated truck	Hannover-Linden (DE)	Conventional train	Sävenäs (SE)	Articulated truck	Göteborg (SE)
58	181	32639	Fredericia (DK)	Articulated truck	Fredericia Havn (DK)	Conventional ship	Oslo (NO)	Articulated truck	Akershus (NO)
59	181	50590	Hamburg (DE)	Articulated truck	Hamburg (DE)	Conventional ship	Fredericia Havn (DK)	Articulated truck	Fredericia (DK)
Commodity group 14: Secondary raw materials & wastes									
60	1	211	Valby (DK)			Articulated truck			Halmstad (SE)
61	2	107	Hamburg (DE)			Articulated truck			Odense S (DK)
62	3	71	Rotenburg (Wumme) (DE)			Articulated truck			Køge (DK)
63	121	13	Ishøj (DK)	Light truck	Padborg (DK)	Articulated truck	Hamburg (DE)	Truck 18-26t	Rotenburg (Wumme) (DE)
64	121	17	Roskilde (DK)	Truck/trailer > 18t	Vejle (DK)	Articulated truck	Hamburg (DE)	Truck/trailer > 18t	Hamburg (DE)
65	131	2	Herzogtum Lauenburg (DE)	Truck 12-18t	Lübeck (DE)	Articulated truck	Rødby Havn (DK)	Truck 12-18t	Midtlolland (DK)
66	131	4	Ostholstein (DE)	Truck/trailer 12-18t	Lübeck (DE)	Articulated truck	Copenhagen (DK)	Truck/trailer 12-18t	Faxe (DK)
67	171	98	Borken (DE)	Articulated truck	Duisburg (DE)	Conventional train	Sävenäs (SE)	Articulated truck	Göteborg (SE)
68	181	1924	Akershus (NO)	Articulated truck	Oslo (NO)	Conventional ship	Kiel (DE)	Articulated truck	Rendsburg-Eckernforde (DE)

Table 12. The GreCOR sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	PRODUCTION ZONE	VEHICLE LEG 1	FIRST TERMINAL	VEHICLE LEG 2	SECOND TERMINAL	VEHICLE LEG 3	CONSUMPTION ZONE
Commodity group 15: Mail & parcels									
69	2	1582	Utrecht (NL)			Articulated truck			Padborg (DK)
70	121	162	Veluwe (NL)	Truck 12-18t	Coevorden (NL)	Articulated truck	Silkeborg (DK)	Truck 12-18t	Middelfart (DK)
71	121	97	Køge (DK)	Truck 12-18t	Køge (DK)	Articulated truck	Marl (DE)	Truck 12-18t	Zuidoost-Noord-Brabant (NL)
72	121	101	Kolding rural (DK)	Truck 12-18t	Kolding (DK)	Articulated truck	Brunsbüttel (DE)	Truck 12-18t	Segeberg (DE)
73	131	67	Køge (DK)	Truck 12-18t	Køge (DK)	Articulated truck	Lübeck (DE)	Truck 12-18t	Herzogtum Lauenburg (DE)
74	131	199	Ringsted (DK)	Truck/trailer 12-18t	Esbjerg (DK)	Articulated truck	Terneuzen (NL)	Truck/trailer 12-18t	Ghent (BE)
75	131	71	Brøndby (DK)	Light truck	Køge (DK)	Articulated truck	Kiel (DE)	Truck 12-18t	Rendsburg-Eckernforde (DE)
76	191	49	Hamburg (DE)	Truck 12-18t	Lübeck (DE)	Ro-Ro ship	Helsingborg (SE)	Truck 12-18t	Glostrup (DK)
77	191	53	Zuidoost-Noord-Brabant (NL)	Truck 12-18t	Antwerp (BE)	Ro-Ro ship	Göteborg (SE)	Truck 12-18t	Køge (DK)
Commodity group 21: Crude oil & natural gas									
78	2	76	Fredericia (DK)			Truck 18-26 t			Rendsburg-Eckernforde (DE)
79	121	23	Rotenburg (Wumme) (DE)	Truck 12-18t	Hamburg (DE)	Articulated truck	Kolding (DK)	Light truck	Kolding city (DK)
80	131	22	Fredericia (DK)	Truck/trailer 12-18t	Fredericia Havn (DK)	Articulated truck	Lübeck (DE)	Truck/trailer 12-18t	Ostholstein (DE)
81	171	74	Rotenburg (Wumme) (DE)	Articulated truck	Hamburg (DE)	Conventional train	Oslo (NO)	Articulated truck	Akershus (NO)
82	181	63484	Fredericia (DK)	Articulated truck	Fredericia Havn (DK)	Conventional ship	Bremen (DE)	Articulated truck	Borken (DE)
Commodity group 22: Fertilizers									
83	2	1716	Fredericia (DK)			Articulated truck			Borken (DE)
84	3	168	Borken (DE)			Articulated truck			Køge (DK)
85	121	13	Ghent (BE)	Truck 12-18t	Terneuzen (NL)	Articulated truck	Odense (DK)	Truck 12-18t	Nyborg (DK)
86	121	12	Nyborg (DK)	Truck 3.5-12t	Odense (DK)	Articulated truck	Amsterdam (NL)	Truck 3.5-12t	Utrecht (NL)
87	121	23	Hannover (DE)	Truck 12-18t	Hannover-Linden (DE)	Articulated truck	Kolding (DK)	Light truck	Kolding city (DK)
88	121	29	Padborg (DK)	Truck 12-18t	Aabenraa Havn (DK)	Articulated truck	Dörpen (DE)	Truck 12-18t	Overig Groningen (NL)
89	131	18	Utrecht (NL)	Truck 12-18t	Amsterdam (NL)	Articulated truck	Esbjerg (DK)	Truck 12-18t	Sorø (DK)
90	131	10	Schleswig-Flensburg (DE)	Truck 12-18t	Flensburg (DE)	Articulated truck	Odense (DK)	Light truck	Odense NØ (DK)
91	131	10	Nyborg (DK)	Truck 3.5-12t	Nyborg Havn (DK)	Articulated truck	Hamburg (DE)	Truck 3.5-12t	Rotenburg (Wumme) (DE)
92	131	10	Rendsburg-Eckernforde (DE)	Truck 12-18t	Kiel (DE)	Articulated truck	Køge (DK)	Truck 12-18t	Køge (DK)
93	171	1460	Akershus (NO)	Articulated truck	Oslo (NO)	Conventional train	Coevorden (NL)	Articulated truck	Veluwe (NL)
94	181	2399	Akershus (NO)	Articulated truck	Oslo (NO)	Conventional ship	Amsterdam (NL)	Articulated truck	Utrecht (NL)

Table 12. The GreCOR sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	PRODUCTION ZONE	VEHICLE LEG 1	FIRST TERMINAL	VEHICLE LEG 2	SECOND TERMINAL	VEHICLE LEG 3	CONSUMPTION ZONE
Commodity group 23: Stone, sand, gravel & quarry products									
95	1	250	Malmö (SE)			Articulated truck			Vesterbro (DK)
96	2	176	Hamburg (DE)			Articulated truck			Assens (DK)
97	2	192	Rendsburg-Eckernforde (DE)			Articulated truck			Padborg (DK)
98	3	46	Hamburg (DE)			Articulated truck			Slagelse (DK)
99	3	10	Segeberg (DE)			Articulated truck			Odense S (DK)
100	121	1	Zuidoost-Noord-Brabant (NL)	Truck 3.5-12t	Marl (DE)	Articulated truck	Padborg (DK)	Light truck	Ishøj (DK)
101	121	30	Overig Groningen (NL)	Articulated truck	Dörpen (DE)	Articulated truck	Århus (DK)	Articulated truck	Haderslev (DK)
102	121	5	Veluwe (NL)	Truck 18-26t	Coevorden (NL)	Articulated truck	Odense (DK)	Truck 18-26t	Nyborg (DK)
103	131	3	Ostholstein (DE)	Truck/trailer 12-18t	Lübeck (DE)	Articulated truck	Køge (DK)	Light truck	Kastrup Lufthavn (DK)
104	131	2	Overig Groningen (NL)	Truck 12-18t	Dörpen (DE)	Articulated truck	Køge (DK)	Truck 12-18t	Køge (DK)
105	131	1	Veluwe (NL)	Truck 3.5-12t	Coevorden (NL)	Articulated truck	Køge (DK)	Light truck	Kastrup Lufthavn (DK)
106	171	195	Borken (DE)	Articulated truck	Duisburg (DE)	Conventional train	Halmstad (SE)	Articulated truck	Halmstad (SE)
107	181	2000	Göteborg (SE)	Articulated truck	Göteborg (SE)	Conventional ship	Antwerp (BE)	Articulated truck	Zuidoost-Noord-Brabant (NL)
Commodity group RESTA: Various - Containerised									
108	171	990	Hannover (DE)	Truck/trailer > 18t	Hannover-Linden (DE)	Combi train	Hallsberg (SE)	Truck/trailer > 18t	Akershus (NO)
109	181	31820	Borken (DE)	Articulated truck	Antwerp (BE)	Containership	Fredericia Havn (DK)	Articulated truck	Fredericia (DK)
110	181	6232	Utrecht (NL)	Articulated truck	Rotterdam (NL)	Containership	Oslo (NO)	Articulated truck	Akershus (NO)
111	181	16020	Ghent (BE)	Articulated truck	Antwerp (BE)	Containership	Göteborg (SE)	Articulated truck	Göteborg (SE)
112	181	171	Hamburg (DE)	Truck/trailer > 18t	Hamburg (DE)	Containership	Malmö (SE)	Truck/trailer > 18t	Malmö (SE)
113	181	15571	Glostrup (DK)	Articulated truck	Københavns Havn (DK)	Containership	Rotterdam (NL)	Articulated truck	Borken (DE)
114	191	4919	Hannover (DE)	Articulated truck	Lübeck (DE)	Ro-Ro ship	Helsingborg (SE)	Articulated truck	Brøndby (DK)
115	191	4132	Borken (DE)	Articulated truck	Bremen (DE)	Ro-Ro ship	Oslo (NO)	Articulated truck	Akershus (NO)
116	191	4484	Ghent (BE)	Articulated truck	Antwerp (BE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Göteborg (SE)
117	191	81	Rendsburg-Eckernforde (DE)	Articulated truck	Lübeck (DE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Göteborg (SE)
118	191	1137	Ghent (BE)	Articulated truck	Ghent (BE)	Ro-Ro ship	Tønsberg (NO)	Articulated truck	Akershus (NO)
119	191	117	Utrecht (NL)	Articulated truck	Amsterdam (NL)	Ro-Ro ship	Esbjerg (DK)	Articulated truck	Kolding city (DK)
120	191	1638	Hannover (DE)	Articulated truck	Hamburg (DE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Göteborg (SE)
121	191	2197	Overig Zeeland (NL)	Articulated truck	Zeebrugge (BE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Göteborg (SE)

Table 12. The GreCOR sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	PRODUCTION ZONE	VEHICLE LEG 1	FIRST TERMINAL	VEHICLE LEG 2	SECOND TERMINAL	VEHICLE LEG 3	CONSUMPTION ZONE
Commodity group RESTB: Various - Non-containerised									
122	1	7250	Hvidovre (DK)			Articulated truck			Malmö (SE)
123	2	20051	Hamburg (DE)			Articulated truck			Haderslev (DK)
124	2	11079	Hannover (DE)			Articulated truck			Fredericia (DK)
125	3	3546	Falster (DK)			Articulated truck			Hamburg (DE)
126	3	753	Faxe (DK)			Articulated truck			Rendsburg-Eckernforde (DE)
127	6	3996	Uddevalla (SE)			Articulated truck			Veluwe (NL)
128	111	250	Göteborg (SE)	Articulated truck	Kungsbacka (SE)	Articulated truck	Copenhagen (DK)	Articulated truck	Valby (DK)
129	121	1759	Ghent (BE)	Articulated truck	Terneuzen (NL)	Articulated truck	Silkeborg (DK)	Articulated truck	Fredericia (DK)
130	121	445	Overig Groningen (NL)	Articulated truck	Dörpen (DE)	Articulated truck	Kolding (DK)	Articulated truck	Kolding rural (DK)
131	121	128	Veluwe (NL)	Truck 12-18t	Coevorden (NL)	Articulated truck	Silkeborg (DK)	Truck 12-18t	Middelfart (DK)
132	121	173	Utrecht (NL)	Truck 12-18t	Amsterdam (NL)	Articulated truck	Odense (DK)	Truck 12-18t	Nyborg (DK)
133	121	182	Valby (DK)	Truck/trailer > 18t	Christiansfeld (DK)	Articulated truck	Duisburg (DE)	Truck/trailer > 18t	Borken (DE)
134	121	122	Ishøj (DK)	Light truck	Padborg (DK)	Articulated truck	Duisburg (DE)	Truck 18-26t	Borken (DE)
135	121	155	Høje Taastrup (DK)	Articulated truck	Høje Taastrup (DK)	Articulated truck	Terneuzen (NL)	Articulated truck	Ghent (BE)
136	121	212	Assens (DK)	Truck/trailer 12-18t	Århus (DK)	Articulated truck	Hamburg (DE)	Truck/trailer 12-18t	Rotenburg (Wumme) (DE)
137	121	662	Fredericia (DK)	Articulated truck	Silkeborg (DK)	Articulated truck	Marl (DE)	Articulated truck	Zuidoost-Noord-Brabant (NL)
138	131	831	Køge (DK)	Truck/trailer > 18t	Køge (DK)	Articulated truck	Hamburg (DE)	Truck/trailer > 18t	Hamburg (DE)
139	131	365	Ringsted (DK)	Articulated truck	Esbjerg (DK)	Articulated truck	Terneuzen (NL)	Articulated truck	Ghent (BE)
140	131	91	Brøndby (DK)	Light truck	Køge (DK)	Articulated truck	Hamburg (DE)	Truck 18-26t	Hamburg (DE)
141	131	111	Midtlolland (DK)	Truck 12-18t	Rødby Havn (DK)	Articulated truck	Kiel (DE)	Truck 12-18t	Rendsburg-Eckernforde (DE)
142	131	63	Ostholstein (DE)	Truck 3.5-12t	Lübeck (DE)	Articulated truck	Fredericia (DK)	Truck 3.5-12t	Haderslev (DK)
143	131	121	Ringsted (DK)	Truck 12-18t	Esbjerg (DK)	Articulated truck	Amsterdam (NL)	Truck 12-18t	Utrecht (NL)
144	131	179	Vesterbro (DK)	Light truck	Copenhagen (DK)	Articulated truck	Duisburg (DE)	Truck/trailer 12-18t	Borken (DE)
145	131	46	Kastrup Lufthavn (DK)	Light truck	Køge (DK)	Articulated truck	Hannover-Linden (DE)	Truck 18-26t	Hannover (DE)
146	131	54	Køge (DK)	Truck 3.5-12t	Køge (DK)	Articulated truck	Dörpen (DE)	Truck 3.5-12t	Overig Groningen (NL)
147	151	8261	Göteborg (SE)	Articulated truck	Kungsbacka (SE)	Articulated truck	Coevorden (NL)	Articulated truck	Veluwe (NL)
148	171	8255	Borken (DE)	Articulated truck	Duisburg (DE)	Short train	Sävenäs (SE)	Articulated truck	Göteborg (SE)
149	171	2429	Malmö (SE)	Articulated truck	Malmö (SE)	Conventional train	Rotterdam (NL)	Articulated truck	Utrecht (NL)
150	181	873999	Hamburg (DE)	Articulated truck	Hamburg (DE)	Conventional ship	Helsingborg (SE)	Articulated truck	Helsingborg (SE)
151	191	48099	Ghent (BE)	Articulated truck	Antwerp (BE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Uddevalla (SE)
152	191	16222	Cloppenburg (DE)	Articulated truck	Bremen (DE)	Ro-Ro ship	Oslo (NO)	Articulated truck	Akershus (NO)
153	191	10146	Borken (DE)	Articulated truck	Lübeck (DE)	Ro-Ro ship	Helsingborg (SE)	Articulated truck	Glostrup (DK)
154	191	7426	Ghent (BE)	Articulated truck	Ghent (BE)	Ro-Ro ship	Tønsberg (NO)	Articulated truck	Akershus (NO)
155	191	2760	Hamburg (DE)	Articulated truck	Hamburg (DE)	Ro-Ro ship	Göteborg (SE)	Articulated truck	Göteborg (SE)
156	191	2568	Utrecht (NL)	Articulated truck	Amsterdam (NL)	Ro-Ro ship	Esbjerg (DK)	Articulated truck	Kolding city (DK)

6. Chain-level indicators

The purpose of this chapter is to present the estimation of KPI values for the sample chains. In addition to the calculation procedures, the chapter will specify the sources used for obtaining the necessary information, as well as the underline assumptions.

In the CPI context, the construction of the ‘basket’ of goods and services is followed by the selection of representative outlets to be contacted for soliciting price information for each and every item in the ‘basket’. The outlet selection is based on specialised market share studies, which determine the number of observations to be obtained from each outlet type. At this lowest level, where prices enter the index, the procedure usually involves the application of an equally weighted formula (such as an arithmetic mean or a geometric mean) for obtaining price indexes, while weights are applied for higher than ‘elementary aggregate’ levels.

This is the procedure that would have been followed in the case a model-based approach hadn’t been selected. In our application, the KPI values at the individual chain level will be evaluated based on available information.

As mentioned in Section 2.3, the corridor assessment KPIs are those of the SuperGreen project: transport cost (from the shipper’s viewpoint), transport time/speed, reliability and frequency of service, and CO_2-eq and SOx emissions. Their estimation is described in the following headings starting from the environmental attributes that comprise the focal area of Activity 3.4. The complete lack of data in relation to service reliability led to the dropping of this indicator from the assessment exercise. Table 18 at the end of the chapter presents the resulting chain-level KPI values.

6.1 CO_2-eq emissions

The CO_2-eq emissions were calculated through the EcoTransIT World web-based tool, which is compatible with the ISO 16258 standard. The “well-to-wheel” option was selected enabling modal comparisons. In terms of input mode, the “extended” option was activated permitting maximum flexibility in describing the chain under examination.

Extensive effort was made to ensure that the chain alignment is in consent with the one specified in Table 12. Each production/consumption zone in LTM is represented by a centroid defined by a pair of latitude / longitude coordinates. The same applies for the intermediate terminals used in 3-leg arrangements. So the “Coordinates” option of EcoTransIT was used for identifying the origin, destination and intermediate stops (through the “via” option). The EcoTransIT “preferred” option proved extremely useful for describing the arrangements involving ferries (3, 6, 131 and 161). In the few cases the alignment proposed by EcoTransIT involved a non-GreCOR route (e.g. the Gedser-Rostock connection) despite having a GreCOR alternative (Rødby-Puttgarden), the tool was forced to calculate the intended alignment by splitting the route in three distinct segments estimated separately. This does not apply in cases where the out-of-GreCOR alignment was specified explicitly by the LTM chain. For Ro-Ro connections not supported by EcoTransIT (e.g. Brevik-Ghent), emissions were calculated from other Ro-Ro routes adjusted for the correct port-to-port distance taken from http://www.sea-distances.org/.

In relation to chain alignment, it is worth mentioning that 3 (out of the 156) chains include the Fredericia-Lübeck segment as involving a ferry link (131). The only possible ferry link between this pair is the consecutive Ro-Ro connections Fredericia-Copenhagen and Copenhagen-Lübeck, a badly sub-optimal option in terms of both time and cost. Normally atypical chains like this should be dropped from the sample. However, for practical purposes it was decided to keep these chains in the sample but follow a ‘land border’ routing (121) instead.

In terms of vehicles used, LTM is not fully compatible with EcoTransIT. The EcoTransIT equivalent types used for each LTM vehicle in the sample appear in Table 13.

Table 13. Correspondence between LTM and EcoTransIT vehicle types

LTM	EcoTransIT
Road transport	
Light goods vehicle	<= 3.5 t
Truck 3.5-12 tonnes	3.5-7.5 t
Truck 12 - 18 tonnes	12-20 t
Truck 18 - 26 tonnes	20-26 t
Truck with trailer 12-18 tonnes	12-20 t
Truck with trailer > 18 tonnes	20-26 t
Articulated truck	26-40 t
Rail transport	
Conventional train	Average train
Combi train	Container train
Short wagon train	Light train
Maritime transport	
Conventional ship	Intra-continental EU (0.5-2k TEU)
Containership	Container aggregate
Ro-Ro ship	Ro-Ro ship

The default settings of EcoTransIT were accepted for all other variables. This includes the emission standards of road vehicles (EURO 5 for articulated trucks and EURO 3 for all other truck types), the Load Factors (LF) and Empty Trip Factors (ETF) for all vehicle types and the average load of a container (10t/TEU). For more information on the default assumptions of the EcoTransIT calculator, please refer to EWI (2014).

6.2 SOx emissions

The EcoTransIT World tool was also used for the SOx emissions. The only complication here stems for the fact that the tool is not in line with the current legislation regarding the maximum allowable sulphur content of marine fuels. As from Jan. 1, 2015, this limit has been reduced from 1% to 0.1% by mass for the so-called SECAs (SOx Emission Control Areas), which include all GreCOR related seas (Baltic Sea, North Sea and the English Channel).

The need for a correction depends on the time horizon of the application at hand. In theory, the fact that the LTM results used for this work concern Year 2010 is not restrictive in the sense that LTM only enters the selection of the sample, which is then assessed in every consecutive year. However, in the present model-based application the model results are also used for KPI estimation. This means that the values reached will refer to Year 2010. In this case, no correction is needed for SOx emissions, as the maximum limit applicable in this year was 1% (it was reduced from 1.5% on Jan. 1, 2010).

Nevertheless and in order to demonstrate the way a correction could be made manually, the EcoTransIT SOx results were finally corrected to incorporate the latest stricter sulphur legislation. It can be easily proved on the basis of the chemical reaction of sulphur oxidation that under normal conditions the weight of SO_2 produced is directly proportional to the sulphur content of the fuel. A reduction from 1% to 0.1% of the sulphur content would, then, lead to a 90% drop in SO_2. However, not all fuel consumed by ships need to be improved. Even under the previous regime, ships at berth (for more than 2 hours) needed to use low sulphur fuel (S 0.1%) for their auxiliary engines running while in port. For the sake of simplicity, it is assumed here that 10% of the fuel consumed was of the S 0.1% quality anyway. In this case, the change will affect the 90% of the fuel previously consumed, which will produce only 10% of the previous SOx emissions.

6.3 Transport cost

Although some more recent cost information was obtained in the framework of on-going DTU Transport modelling work and the SWIFTLY Green (2015) report, the high risk of inconsistency due to its partial coverage precluded its use. The LTM 2010 values were applied instead. The road transport costs by vehicle type have been specified in Table 3. The corresponding rail and maritime transport costs are shown in Table 14.

Table 14. Default LTM cost figures for rail and maritime transport (Year 2010)

Type description	Capacity (tonnes)	Load cost (DKK/tonne)	Distance cost (DKK/km)	Time cost (DKK/h)
Rail transport				
Conventional system train	1.900	100	150	4.500
Conventional wagon train, short	558	45	45	1.900
Conventional wagon train, long	837	45	60	3.100
Combi train	1.500	35	120	4.200
Maritime transport				
Conventional ship 0-10,000 DWT	4.300	25	45	1.700
Conventional ship 10,001-50,000 DWT	29.000	16	136	3.500
Conventional ship > 50,000 DWT	140.000	20	312	8.700
Containership	26.000	32	106	5.300
Ro-Ro ship	7.900	37	135	5.200

In calculating distance-, time- and ferry-related costs, the number of shipments is required. This is estimated on the basis of the vehicle capacity of LTM (Tables 3 and 14) multiplied by an utilisation factor of 60% (70% for containerships). It is noted that this is different from the utilisation factor of EcoTransIT (that enters the emissions calculation), which is calculated through the default load and empty trip factors[5] by the formula:

Capacity utilisation = Load factor / (1 + empty trip factor)

Differences, however, are mitigated by the fact that the vehicle capacities of LTM are lower than the corresponding EcoTransIT estimates.

Time-related costs are calculated on the basis of vehicle running times as estimated in Section 6.4.

[5] Load Factor: mass of weight / payload capacity
Empty trip factor: Distance empty / Distance loaded

All cost figures are denominated in Danish Kroner (DKK) of 2010. They can be converted to EUR 2010 by applying the average exchange rate:

7.45 DKK = 1 EUR 2010

6.4 Transport time/speed

Speed is a concept that needs to be defined carefully, as there is a wide range of definitions (and corresponding values) serving different purposes. The Transport Market Studies of the core network corridors talk about maximum allowable speed, as they look at transport from the infrastructural perspective. Transport planners and network designers (ETIS Plus, TENTec) are preoccupied with average running speeds, as they are concerned with the capacities of the network links. Shippers, on the other hand, are interested on the overall time required for a door-to-door service, and this is the perspective of the present analysis. The average service speed is calculated by dividing distance with the overall time elapsed between the beginning of the loading operation at the origin and the end of cargo unloading at the destination.

Overall transport time, then, consists of the cargo handling, in-vehicle and ferry components. The relevant calculations are based on the assumptions summarised in Tables 15, 16 and 17 respectively.

Table 15. Time requirements for cargo handling operations

Type description	Loading (hours)	Unloading (hours)
Road transport		
Light goods vehicle	0,5	0,5
Truck 3.5-12 tonnes	0,5	0,5
Truck 12 - 18 tonnes	1	1
Truck 18 - 26 tonnes	1	1
Truck with trailer 12-18 tonnes	1	1
Truck with trailer > 18 tonnes	1,5	1,5
Articulated truck	2	2
Rail transport		
Combi trains	6	6
All other trains	24	24
Maritime transport		
Conventional ship	48	48
Containership	24	24
Ro-Ro ship	2	0,5
Ferry	0,5	-

Table 16. Average vehicle speeds

Type description	Speed (km/h)
Road transport	
Feeder service (Leg 1, Leg 3)	70,00
Long haul (Leg 2)	40,00
Rail transport	
All trains	80,00
Maritime transport	
Conventional ships	25,93 (14 kn)
Containership	29,63 (16 kn)

Table 17. Basic characteristics of Ro-Ro and ferry connections

Type description	Speed (km/h)	Frequency (services/week)
Ro-Ro connections		
Brevik-Ghent	30,00	2
Lübeck-Copenhagen	9,00	19
Gothenburg-Ghent	30,00	6
Esbjerg-Rotterdam	21,00	1
Kiel-Gothenburg	14,50	7
Kiel-Oslo	20,00	7
Ferry connections		
Rødby-Puttgarden	0,75	every 1/2 h
Bøjden-Fynshav	0,83	12/day

It needs to be noted that the average long haul speed of road vehicles (Table 16) is assumed to be lower than the corresponding feeder service figure (40 against 70 km/h) due to the driver resting time requirements of the long haul journeys. The speeds and frequencies of Table 17 are based on actual service schedules.

6.5 Frequency of service

This indicator is meaningful only for scheduled services. This includes Ro-Ro, containership and train services (with the exception of ad hoc block trains). Ro-Ro service frequencies are reported in Table 17. No data was obtained for containership and train services. Ferry frequency data was identified but do not enter the calculations, as these figures are never bounding.

All other services (road and convention ship) are arranged on demand. For these cases, only observed frequencies (number of shipments per reporting period) can be calculated. It should be underlined, however, that these figures indicate demand rather than frequency of service in the sense of availability, which is the purpose of this indicator. As such, the results of this KPI can only be used for comparing Ro-Ro services.

Theoretically, in multi-leg arrangements, the frequency of the chain is the lowest among the frequencies of the constituent legs. For the 3-leg chains of this study, it is the frequency of the long haul segment (Leg 2) that is usually bounding. An exception to this rule is the case of massive flows involving rail or maritime transport for the main haul. In such cases, as is for example Chain 150 (874,000 tonnes of chemical products moving from Hamburg to Helsingborg), the frequency of the feeder service can also be of interest due to its vast character. In this particular example, the requirement for 1,624 trucks per week (one every 6 minutes) is highly improbable; a continuous form of cargo handling (e.g. a conveyor belt) is much more likely.

Frequencies are rounded to the closest integer number and cannot be zero.

Table 18. KPI values of the sample chains

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	DISTANCE				T *KM	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)
			ROAD	RAIL	SEA	TOTAL						
Commodity group 1A: Agro products - Containerised												
1	191	351	263,47	0,00	1.074,16	1.337,63	469.508	0,5743	33,22	2,00	1.152,11	0,85916
2	191	86	277,54	0,00	218,81	496,35	42.686	1,3861	25,50	19,00	1.227,57	1,46211
3	191	263	336,52	0,00	1.000,42	1.336,94	351.616	0,6256	32,37	6,00	1.145,87	1,04951
4	191	248	241,44	0,00	531,52	772,96	191.694	0,7961	24,98	1,00	1.073,49	0,83465
5	191	183	234,32	0,00	415,52	649,84	118.921	0,8061	26,69	7,00	1.054,57	0,82372
Commodity group 1B: Agro products - Non-containerised												
6	2	239	380,26	0,00	0,00	380,26	90.882	1,5347	28,15	0,44	76,25	0,08539
7	3	57	582,46	0,00	18,00	600,46	34.226	1,6525	30,31	0,12	75,38	0,09437
8	121	36	690,96	0,00	0,00	690,96	24.875	1,5899	32,54	0,06	87,24	0,09769
9	121	211	770,00	0,00	0,00	770,00	162.470	1,4009	36,70	0,38	74,54	0,08340
10	121	7	905,46	0,00	0,00	905,46	6.338	2,1008	33,35	0,02	93,87	0,10492
11	131	25	498,84	0,00	18,00	516,84	12.921	1,9084	26,16	0,04	95,11	0,11719
12	131	29	331,04	0,00	18,00	349,04	10.122	1,6497	20,62	0,06	81,24	0,10724
13	131	39	359,56	0,00	531,52	891,08	34.752	1,0733	24,32	1,00	114,49	0,09485
14	171	820	71,79	1.131,07	0,00	1.202,86	986.345	0,3331	16,90	1,52	19,80	0,02338
15	181	4668	87,73	0,00	829,44	917,17	4.281.350	0,1566	6,68	8,67	13,10	0,02394
Commodity group 2: Coal & lignite												
16	2	6243	261,64	0,00	0,00	261,64	1.633.419	1,5537	24,82	11,60	73,47	0,08265
17	5	180	1.370,20	0,00	0,00	1.370,20	246.636	1,4932	35,82	0,33	72,98	0,08109
18	6	70	692,26	0,00	415,52	1.107,78	77.545	0,9707	35,86	7,00	94,91	0,08747
19	171	23	112,31	1.687,99	0,00	1.800,30	41.407	0,2973	22,87	0,04	14,97	0,01809
20	181	3627	43,37	0,00	671,50	714,87	2.592.833	0,1262	5,48	6,73	27,86	0,03395
Commodity group 3: Iron ore & non-ferrous metal ores												
21	2	242	265,42	0,00	0,00	265,42	64.232	1,5239	24,96	0,44	76,91	0,10447
22	2	55	107,43	0,00	0,00	107,43	5.909	1,4976	16,07	0,10	74,47	0,08293
23	3	29	286,67	0,00	14,57	301,24	8.736	1,6411	24,10	0,06	97,44	0,08242
24	3	18	274,89	0,00	18,00	292,89	5.272	1,7362	24,16	0,04	78,03	0,10665
25	121	15	1.123,95	0,00	0,00	1.123,95	16.859	1,0417	35,79	0,02	73,88	0,08209
26	121	10	837,82	0,00	0,00	837,82	8.378	1,6863	31,96	0,02	90,71	0,10026
27	121	15	1.012,11	0,00	0,00	1.012,11	15.182	3,3465	36,09	0,02	128,44	0,14359
28	121	23	793,91	0,00	0,00	793,91	18.260	1,6428	31,35	0,04	82,15	0,09255
29	131	4	169,10	0,00	18,00	187,10	748	3,7645	14,07	0,02	81,53	0,12264
30	131	11	223,08	0,00	218,81	441,89	4.861	1,2447	19,48	19,00	109,65	0,09602
31	131	6	817,85	0,00	18,00	835,85	5.015	2,5804	28,93	0,02	79,79	0,09659
32	131	24	882,84	0,00	18,00	900,84	21.620	1,3360	27,18	0,04	74,77	0,09064
33	171	871	45,49	545,25	0,00	590,74	514.535	0,4480	9,31	1,61	22,95	0,01918
34	181	2627	248,18	0,00	665,39	913,57	2.399.948	0,3568	6,86	4,89	38,97	0,04569

Table 18. KPI values of the sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	DISTANCE ROAD	DISTANCE RAIL	DISTANCE SEA	DISTANCE TOTAL	T *KM	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)
Commodity group 6: Wood products - Non-containerised												
35	2	1985	246,02	0,00	0,00	246,02	488.350	1,5525	24,24	3,68	73,72	0,08191
36	2	589	315,76	0,00	14,57	330,33	194.566	1,4788	27,77	1,09	95,11	0,08013
37	2	220	577,59	0,00	0,00	577,59	127.070	1,5162	31,32	0,40	73,42	0,07870
38	3	222	185,38	0,00	18,00	203,38	45.150	1,5464	20,58	0,42	78,47	0,11700
39	3	152	140,77	0,00	18,00	158,77	24.133	1,5360	18,11	0,29	81,13	0,12815
40	121	229	912,77	0,00	0,00	912,77	209.024	1,4180	37,84	0,42	73,34	0,08061
41	121	24	531,53	0,00	0,00	531,53	12.757	1,4159	23,59	0,04	76,20	0,08607
42	131	46	629,24	0,00	18,00	647,24	29.773	1,2860	33,50	0,08	75,45	0,09328
43	131	30	375,94	0,00	531,52	907,46	27.224	2,5288	26,02	7,00	197,75	0,18884
44	171	2498	34,21	906,29	0,00	940,50	2.349.369	0,3373	13,87	4,64	18,06	0,01923
45	181	208000	259,14	0,00	634,42	893,56	185.860.480	0,3777	6,76	386,53	26,33	0,03635
46	181	78381	72,96	0,00	1.150,83	1.223,79	95.921.884	0,1076	8,19	145,66	10,44	0,02127
47	181	15500	131,66	0,00	1.061,17	1.192,83	18.488.865	0,1658	8,13	28,81	14,01	0,02474
Commodity group 7: Coke & petroleum products												
48	1	567	634,66	0,00	0,00	634,66	359.852	1,5395	31,95	1,05	72,25	0,08059
49	2	465	183,29	0,00	0,00	183,29	85.230	1,5630	21,36	0,86	73,68	0,08248
50	3	112	475,83	0,00	18,00	493,83	55.309	1,5415	28,80	0,21	75,46	0,09655
51	5	158	1.655,48	0,00	0,00	1.655,48	261.566	1,5001	36,47	0,29	72,64	0,08029
52	111	630	961,23	0,00	0,00	961,23	605.575	1,4916	35,73	1,17	72,61	0,08186
53	121	23	979,24	0,00	0,00	979,24	22.523	3,0814	38,63	0,04	176,71	0,19758
54	131	21	296,23	0,00	0,00	296,23	6.221	1,6002	19,73	0,04	79,89	0,08986
55	151	25	1.249,44	0,00	0,00	1.249,44	31.236	1,3815	34,34	0,04	84,52	0,09508
56	161	205	309,28	0,00	1.074,16	1.383,44	283.605	0,6379	33,81	2,00	118,59	0,08924
57	171	273	66,87	979,26	0,00	1.046,13	285.593	0,3505	15,12	0,50	16,28	0,02048
58	181	32639	49,20	0,00	543,20	592,40	19.335.344	0,1603	4,71	60,66	12,22	0,02298
59	181	50590	8,33	0,00	418,06	426,39	21.571.070	0,1081	3,55	94,01	7,60	0,01850
Commodity group 14: Secondary raw materials & wastes												
60	1	211	200,83	0,00	0,00	200,83	42.375	1,5284	22,26	0,38	72,92	0,08165
61	2	107	315,78	0,00	0,00	315,78	33.788	1,4948	26,55	0,19	73,10	0,08198
62	3	71	346,32	0,00	18,00	364,32	25.867	1,5452	26,19	0,13	76,44	0,10200
63	121	13	535,28	0,00	0,00	535,28	6.959	5,2624	32,60	0,02	172,45	0,19400
64	121	17	473,73	0,00	0,00	473,73	8.053	1,9159	24,09	0,04	83,89	0,09391
65	131	2	148,43	0,00	18,00	166,43	333	6,0310	13,49	0,02	96,47	0,14433
66	131	4	96,47	0,00	218,81	315,28	1.261	1,9528	15,10	19,00	129,66	0,10640
67	171	98	43,06	1.158,26	0,00	1.201,32	117.729	0,3084	16,90	0,17	15,46	0,01818
68	181	1924	64,32	0,00	666,68	731,00	1.406.444	0,1561	5,60	3,57	13,06	0,02339

Table 18. KPI values of the sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	DISTANCE ROAD	RAIL	SEA	TOTAL	T *KM	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)
Commodity group 15: Mail & parcels												
69	2	1582	653,52	0,00	0,00	653,52	1.033.869	1,5346	32,13	2,93	73,51	0,08222
70	121	162	815,03	0,00	0,00	815,03	132.035	1,7105	31,15	0,31	87,17	0,09770
71	121	97	904,26	0,00	0,00	904,26	87.713	1,5813	31,18	0,17	82,54	0,09235
72	121	101	282,88	0,00	0,00	282,88	28.571	1,7831	19,91	0,19	88,90	0,09940
73	131	67	266,40	0,00	18,00	284,40	19.055	1,5685	18,54	0,12	86,63	0,11783
74	131	199	412,54	0,00	531,52	944,06	187.868	1,0943	25,25	7,00	123,04	0,10626
75	131	71	258,49	0,00	18,00	276,49	19.631	2,2390	19,44	0,13	97,66	0,13033
76	191	49	288,69	0,00	218,81	507,50	24.868	2,1617	25,86	19,00	137,93	0,16789
77	191	53	560,80	0,00	1.000,42	1.561,22	82.745	1,4785	35,07	6,00	130,16	0,12432
Commodity group 21: Crude oil & natural gas												
78	2	76	185,54	0,00	0,00	185,54	14.101	1,8051	27,95	0,27	97,87	0,10992
79	121	23	325,51	0,00	0,00	325,51	7.487	1,6909	22,86	0,04	92,30	0,09964
80	131	22	296,23	0,00	0,00	296,23	6.517	1,6006	19,73	0,04	80,10	0,08961
81	171	74	124,20	1.161,63	0,00	1.285,83	95.151	0,3604	17,79	0,13	14,50	0,01902
82	181	63484	239,80	0,00	534,92	774,72	49.182.324	0,4050	6,05	117,98	27,14	0,03745
Commodity group 22: Fertilizers												
83	2	1716	591,50	0,00	0,00	591,50	1.015.014	1,5361	31,48	3,18	73,89	0,08177
84	3	168	605,32	0,00	18,00	623,32	104.718	1,4964	30,58	0,31	75,21	0,09368
85	121	13	994,65	0,00	0,00	994,65	12.930	1,2914	31,11	0,02	77,88	0,08669
86	121	12	861,65	0,00	0,00	861,65	10.340	1,4818	32,05	0,02	84,62	0,09604
87	121	23	433,85	0,00	0,00	433,85	9.979	1,5537	25,10	0,04	82,28	0,09280
88	121	29	532,97	0,00	0,00	532,97	15.456	1,7879	26,67	0,06	85,99	0,09660
89	131	18	375,91	0,00	531,52	907,43	16.334	1,2579	24,61	7,00	123,11	0,10503
90	131	10	143,06	0,00	14,57	157,63	1.576	2,1498	13,62	0,02	111,69	0,15503
91	131	10	372,64	0,00	14,57	387,21	3.872	2,0614	24,71	0,02	116,75	0,14240
92	131	10	249,37	0,00	18,00	267,37	2.674	1,6655	17,85	0,02	86,60	0,11920
93	171	1460	140,63	1.506,36	0,00	1.646,99	2.404.605	0,3324	21,43	2,70	15,41	0,01857
94	181	2399	83,34	0,00	940,01	1.023,35	2.455.017	0,1370	7,23	4,45	12,01	0,02283

Table 18. KPI values of the sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	DISTANCE				T *KM	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)
			ROAD	RAIL	SEA	TOTAL						
Commodity group 23: Stone, sand, gravel & quarry products												
95	1	250	36,03	0,00	0,00	36,03	9.008	1,7069	7,35	0,46	73,27	0,08104
96	2	176	301,91	0,00	0,00	301,91	53.136	1,5451	26,14	0,33	73,40	0,08224
97	2	192	107,43	0,00	0,00	107,43	20.627	1,6244	16,07	0,36	73,69	0,08242
98	3	46	289,61	0,00	18,00	307,61	14.150	1,3642	24,63	0,08	76,91	0,10631
99	3	10	230,52	0,00	14,57	245,09	2.451	1,5898	22,09	0,02	78,36	0,10460
100	121	1	918,13	0,00	0,00	918,13	918	12,4659	37,73	0,02	229,81	0,26140
101	121	30	796,46	0,00	0,00	796,46	23.894	1,4649	37,40	0,06	74,08	0,08287
102	121	5	708,31	0,00	0,00	708,31	3.542	2,9572	28,99	0,02	78,50	0,08612
103	131	3	286,60	0,00	18,00	304,60	914	5,3263	20,82	0,02	139,05	0,17478
104	131	2	620,10	0,00	18,00	638,10	1.276	6,8903	27,26	0,02	86,12	0,10542
105	131	1	682,86	0,00	18,00	700,86	701	13,9217	30,69	0,02	121,64	0,14635
106	171	195	48,86	1.005,22	0,00	1.054,08	205.546	0,3342	15,22	0,36	18,05	0,02116
107	181	2000	108,20	0,00	1.057,53	1.165,73	2.331.460	0,1466	7,97	3,72	29,79	0,03592
Commodity group REST A: Various - Containerised												
108	171	990	380,05	1.177,55	0,00	1.557,60	1.542.024	0,6101	40,83	2,88	328,79	0,37224
109	181	31820	243,04	0,00	983,61	1.226,65	39.032.003	0,2776	13,24	59,13	268,78	0,53006
110	181	6232	104,22	0,00	1.054,95	1.159,17	7.223.947	0,1572	12,45	11,58	218,44	0,78901
111	181	16020	51,09	0,00	1.057,53	1.108,62	17.760.092	0,1093	12,00	29,76	195,72	0,49161
112	181	171	13,02	0,00	503,03	516,05	88.245	0,1499	7,25	0,50	194,57	0,49628
113	181	15571	278,77	0,00	996,65	1.275,42	19.859.565	0,2917	13,62	28,94	276,14	0,77668
114	191	4919	458,95	0,00	218,81	677,76	3.333.901	1,0285	26,01	19,00	874,35	0,91229
115	191	4132	494,16	0,00	653,41	1.147,57	4.741.759	0,7768	30,55	7,00	1.006,38	0,81866
116	191	4484	171,31	0,00	1.000,42	1.171,73	5.254.037	0,5649	27,28	6,00	1.216,69	1,09393
117	191	81	213,89	0,00	415,52	629,41	50.982	0,7977	22,43	7,00	1.054,49	0,78860
118	191	1137	263,47	0,00	1.074,16	1.337,63	1.520.885	0,5736	30,22	2,00	1.151,45	0,85968
119	191	117	225,84	0,00	531,52	757,36	88.611	0,7666	21,81	1,00	1.084,59	0,83792
120	191	1638	308,32	0,00	415,52	723,84	1.185.650	0,8320	24,62	7,00	1.011,80	0,81855
121	191	2197	129,79	0,00	1.000,42	1.130,21	2.483.071	0,5444	26,68	6,00	1.204,56	0,86941

Table 18. KPI values of the sample chains (continued)

NO OF CHAIN	CHAIN TYPE	ANNUAL TONNES	DISTANCE				T *KM	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)
			ROAD	RAIL	SEA	TOTAL						
Commodity group REST B: Various - Non-containerised												
122	1	7250	39,67	0,00	0,00	39,67	287.608	1,7043	7,95	13,48	73,02	0,07997
123	2	20051	214,99	0,00	0,00	214,99	4.310.764	1,5594	22,93	37,26	73,54	0,08235
124	2	11079	445,18	0,00	0,00	445,18	4.932.149	1,5432	29,42	20,60	73,40	0,08211
125	3	3546	203,28	0,00	18,00	221,28	784.659	1,5157	21,42	6,60	79,46	0,11392
126	3	753	207,35	0,00	18,00	225,35	169.689	1,5150	21,60	1,40	78,75	0,11446
127	6	3996	592,29	0,00	415,52	1.007,81	4.027.209	0,9197	34,21	7,00	97,09	0,08657
128	111	250	339,52	0,00	0,00	339,52	84.880	1,4789	28,39	0,46	73,23	0,08200
129	121	1759	1.085,72	0,00	0,00	1.085,72	1.909.781	1,4750	36,84	3,26	73,53	0,08296
130	121	445	592,57	0,00	0,00	592,57	263.694	1,4502	34,06	0,82	73,91	0,08354
131	121	128	815,03	0,00	0,00	815,03	104.324	1,6556	31,15	0,23	87,23	0,09768
132	121	173	861,65	0,00	0,00	861,65	149.065	1,6102	29,83	0,33	76,14	0,08392
133	121	182	838,12	0,00	0,00	838,12	152.538	1,8101	29,86	0,35	81,36	0,09106
134	121	122	818,88	0,00	0,00	818,88	99.903	4,0139	33,97	0,23	218,41	0,24424
135	121	155	1.113,32	0,00	0,00	1.113,32	172.565	1,5096	35,74	0,29	73,85	0,08018
136	121	212	543,46	0,00	0,00	543,46	115.214	1,6604	28,10	0,40	94,43	0,10580
137	121	662	897,11	0,00	0,00	897,11	593.887	1,4318	37,54	1,23	73,53	0,08261
138	131	831	287,07	0,00	18,00	305,07	253.513	1,8333	16,67	1,55	77,78	0,10466
139	131	365	412,54	0,00	531,52	944,06	344.582	0,8974	28,27	1,00	106,61	0,08782
140	131	91	303,83	0,00	18,00	321,83	29.287	2,1180	20,71	0,17	109,07	0,14044
141	131	111	131,40	0,00	18,00	149,40	16.583	1,8092	12,47	0,21	100,19	0,15143
142	131	63	342,41	0,00	0,00	342,41	21.572	1,9846	23,39	0,12	117,75	0,13165
143	131	121	387,84	0,00	531,52	919,36	111.243	1,1962	24,82	1,00	123,02	0,10534
144	131	179	507,31	0,00	218,81	726,12	129.975	1,3239	28,20	19,00	90,94	0,09090
145	131	46	498,84	0,00	18,00	516,84	23.775	1,9975	26,16	0,08	110,97	0,13604
146	131	54	620,10	0,00	18,00	638,10	34.457	1,8176	29,81	0,10	108,75	0,13155
147	151	8261	1.162,80	0,00	0,00	1.162,80	9.605.891	1,4862	36,84	15,34	73,50	0,08224
148	171	8255	43,06	1.158,26	0,00	1.201,32	9.916.897	0,2883	16,90	15,34	15,43	0,01825
149	171	2429	69,69	1.086,80	0,00	1.156,49	2.809.114	0,3377	16,39	4,51	18,79	0,02065
150	181	873999	17,32	0,00	488,37	505,69	441.972.554	0,1137	4,11	1,00	8,56	0,01944
151	191	48099	222,03	0,00	1.000,42	1.222,45	58.798.623	0,5898	27,99	6,00	120,22	0,09071
152	191	16222	334,21	0,00	653,41	987,62	16.021.172	0,7175	28,00	7,00	111,42	0,08927
153	191	10146	619,29	0,00	218,81	838,10	8.503.363	1,0507	29,57	19,00	89,96	0,09559
154	191	7426	263,48	0,00	1.074,16	1.337,64	9.933.315	0,5749	30,22	2,00	120,07	0,08946
155	191	2760	126,22	0,00	415,52	541,74	1.495.202	0,7224	20,21	7,00	117,32	0,09015
156	191	2568	225,89	0,00	531,52	757,41	1.945.029	0,7904	21,81	1,00	143,75	0,12107

7. KPI aggregation

The purpose of this chapter is to produce the KPI indexes at all higher-than-chain levels. In all instances, the cost, CO_2-eq and SOx emission indicators that are expressed on a per tonne-km (tkm) basis are aggregated using the relevant tkm figures as weights. For the speed and frequency indicators, the annual tonnes have been selected as the most appropriate weight.

The first type of aggregation concerns the chain types within each commodity group (Level 3 of Figure 17). To continue working on the Commodity 22 (fertilizers) example of Chapter 5, we need to produce aggregate indicators for all 6 chain types (2, 3, 121, 131, 171 and 181) of Commodity group 22 (refer to Table 9). There is nothing to be done for chain types represented by a single chain. In these cases (2, 3, 171 and 181 of our example) the indicators of the corresponding chains (83, 84, 93 and 94 of Table 12 respectively) serve as the KPIs of the entire chain type. However, the indicators of the 4 chains representing Type 121 (85, 86, 87 and 88) have to be combined into composite figures. This is done by applying the simple weighted average formula using as weights the tkm of each chain for combining the cost, CO_2-eq and SOx emission KPIs, and the annual tonnes for combining the speed and frequency indicators. The same procedure is followed for constructing the composite indicators of Chain type 131 using the respective representative chains (89, 90, 91 and 92). All Level 3 KPIs produced in this way appear in Appendix I.

We are now ready to proceed to the second type of aggregation, moving from chain type groups (Level 3) to commodity groups (Level 2). The same methodology is applied for reaching these higher level indicators. The only difference concerns the weights used in the process. Now, the weights are not the tkm and tonnes of the participating chains but the "adjusted" ones of Appendix I, taking also into consideration the chain types not represented in the sample.

An additional step is required for the two cases where there are commodity sub-groups; agricultural and various products. Here the commodity group KPIs are produced by the respective sub-group ones by applying the direct weighted average method.

The same direct weighted averaging is used for the third type of aggregation converting commodity group indicators (Level 2) to corridor KPIs (Level 1), which appear at the end of Appendix I under the "Grand total" label.

The final step of indexing involves a normalisation procedure setting the corridor-level values of each KPI to 100.0 and converting all other values accordingly. An index constructed in this way allows the comparison of two sets of values either over time (temporal indexes) or transport modes (modal indexes) for a common commodity or group of commodities.

The resulting corridor indexes by commodity group are summarised in Table 19 and Figure 21. Even after excluding frequency which, for most chains is basically meaningless, the fluctuations in KPI values are impressive.

Table 19. GreCOR indexes by commodity group

Commodity group		KPI Indexes				
No.	Description	COST	SPEED	FREQ.	CO_2-eq	SOx
1	Agricultural products	77,4	107,3	12,2	107,9	68,2
2	Coal & lignite	41,1	58,0	12,9	42,4	32,4
3	Iron ore & metal ores	110,5	76,7	7,8	60,6	45,1
6	Wood & products	76,2	72,6	518,6	33,2	30,2
7	Coke & petroleum products	35,7	38,9	146,7	15,6	19,7
14	Raw material & wastes	66,9	68,3	5,9	26,9	26,2
15	Mail & parcels	343,8	243,7	7,2	131,2	87,4
21	Crude oil & natural gas	94,4	55,5	210,7	39,2	33,9
22	Fertilizers	249,1	203,6	4,8	86,6	61,9
23	Stone & quarry products	109,3	98,4	5,1	54,1	40,7
R	All other commodities	129,5	132,6	27,5	163,8	173,2
	Grand total	100,0	100,0	100,0	100,0	100,0

At first view it was thought that the very high values for cost, speed and CO_2-eq emissions for the Mail & parcels group can be explained by the small size of the vehicles employed and the necessity for speedy delivery that characterises these cargoes. But this does not seem to be the case for fertilizers that also exhibit very high costs and speeds. A closer look shows that the common feature of these two commodity groups is the low share of maritime transport in the respective trade. It was, thus, decided to regroup the chains by mode to check this hypothesis.

The results are shown in Table 20 and Figure 22. It is confirmed that shipping is by far the least expensive and slowest mode of transport. It is also characterised by the best GHG emission performance, while its SOx emissions are slightly below average. Talking about modes, rail transport seems to exhibit positive behaviour in relation to all KPIs examined, as its performance is below average in terms of cost, CO_2-eq and SOx emissions, and above average in terms of speed.

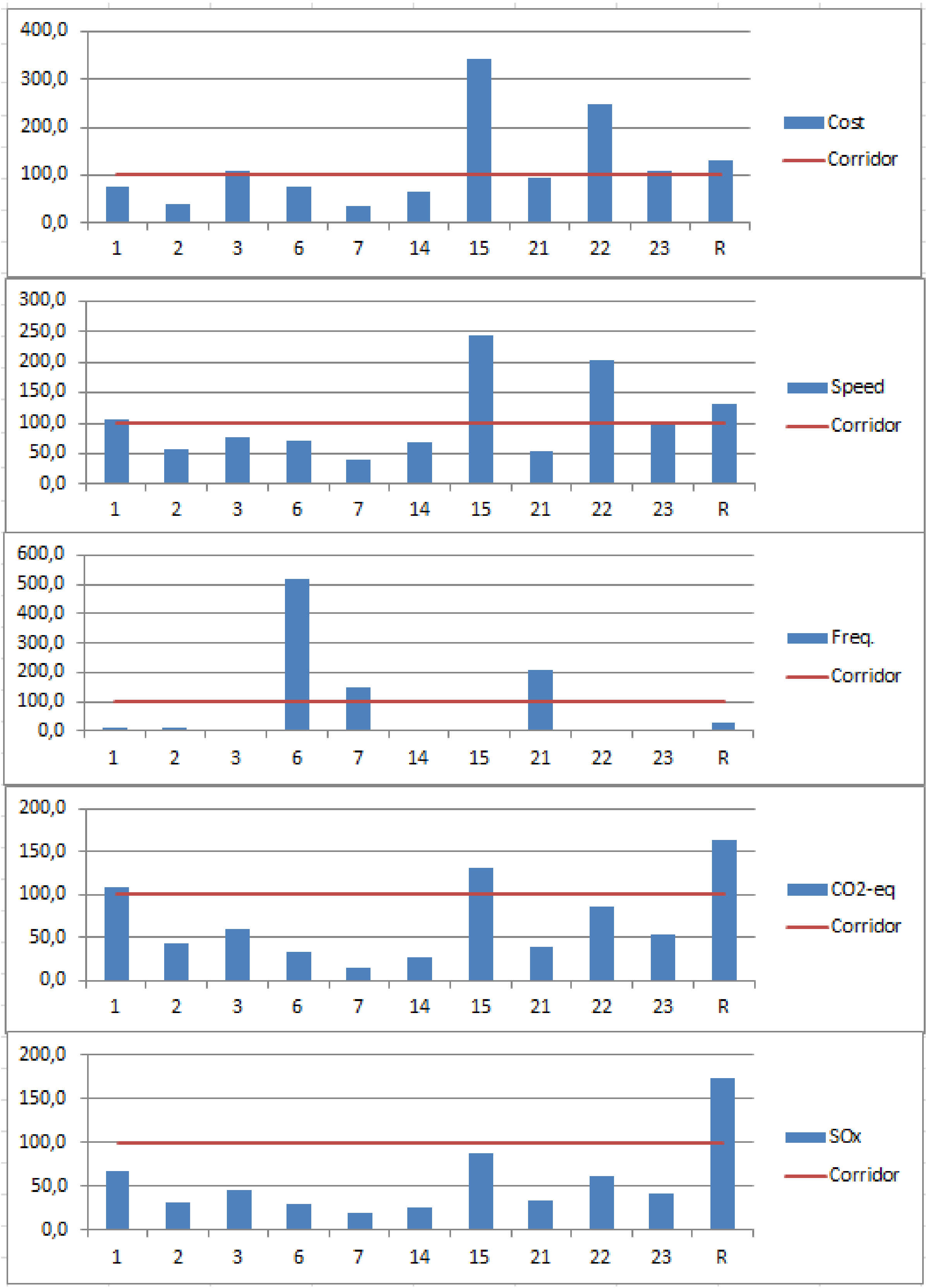

Figure 21. GreCOR indexes by commodity group

Table 20. GreCOR indexes by mode

Mode	KPI Indexes				
	COST	SPEED	FREQ.	CO_2-eq	SOx
Road	344,6	217,5	23,3	113,9	80,4
Rail	79,0	154,4	14,0	69,5	50,1
Shipping	42,6	50,8	133,7	65,9	92,8
Ro-Ro shipping	158,1	233,9	14,4	540,2	284,9
Grand total	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

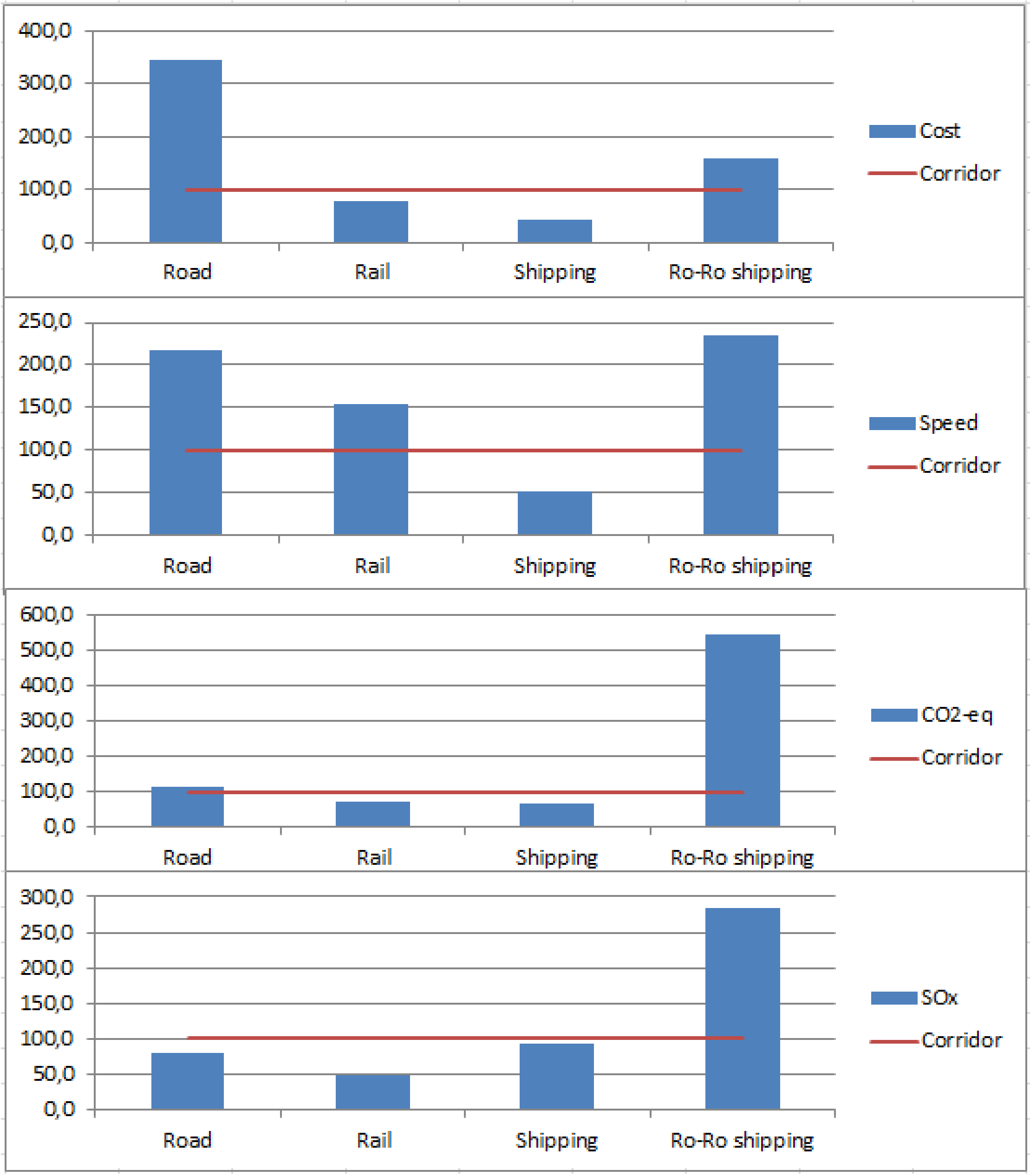

Figure 22. GreCOR indexes by mode

On the other hand, the speed of Ro-Ro shipping (which surprisingly is higher than road) comes at an enormous environmental cost, while its financial cost is also about 58% above average.

Table 21. Composition of the shipping index

Mode	KPI Indexes				
	COST	SPEED	FREQ.	CO_2-eq	SOx
Containerships	53,3	107,8	77,0	358,9	545,8
Conventional ships	41,0	42,6	141,8	20,3	22,3
Total shipping	**42,6**	**50,8**	**133,7**	**65,9**	**92,8**

Table 21 shows that shipping consists of two rather diverse sectors. Unlike conventional ships, which are the slowest of all transport means, containerships sail at above corridor-level average speed. However, they produce 3.6 times as much GHG emissions as the average GreCOR modality, while their SOx emissions are even more intense at 545.8 index points. On the contrary, the environmental performance of conventional shipping brings the total score of maritime transport at below average levels.

Table 22. Comparison between 1-leg and 3-leg road arrangements

Mode	KPI Indexes				
	COST	SPEED	FREQ.	CO_2-eq	SOx
1-leg road chains	344,1	203,5	31,3	108,7	78,6
3-leg road chains	345,4	247,6	6,1	121,7	83,2
Total road	**344,6**	**217,5**	**23,3**	**113,9**	**80,4**

The comparison between1-leg and 3-leg road chains of Table 22 reveals higher speed for the 3-leg arrangements, which reflects the fact that no extra resting time is required for the driver along the shorter feeder voyages. However, this comes at an environmental cost due to smaller vehicles usually employed for the first- and last-mile legs of the journeys.

8. Conclusions

The preceding chapters of this report presented the work performed and the results achieved under Activity 3.4 of the GreCOR project, which aims at “developing a general method for measuring the environmental consequences of the operations in this green corridor including the logistic hubs.” The purpose of this chapter is to summarise the conclusions of this work in terms of both methodology and results, and to present recommendations for further development and refinement of the method applied here.

8.1 Methodological aspects

The method developed here and described in Chapter 2 is a variation of the methodology proposed by the SuperGreen project for green corridor applications, which involves:

- disintegrating the corridor into transport chains;
- selecting a representative set of typical transport chains resembling the ‘basket’ of goods and services used for calculating the Consumer Price Index (CPI);
- estimating periodically KPI values for each and every chain of the selected sample; and
- aggregating these values into corridor-level KPIs by using appropriate weights and methods.

The GreCOR application of this report, which happens to be the first implementation attempt of the method after taking its final form described above, deviates from SuperGreen with regard to the main source of information. While SuperGreen suggests a ‘study-based’ approach using the Transport Market Studies of the TEN-T Core Network Corridors and/or the corresponding Rail Freight Corridors for constructing the corridor sample, timing constraints forced GreCOR to rely on a ‘model-based’ approach using the Danish National Traffic Model (LTM) as the principal source of information.

A further and maybe even more important discrepancy in comparison to SuperGreen relates to the source of data for estimating the KPIs of the sample chains. SuperGreen suggests the use of published material supported by interviews with logistics stakeholders active in the corridor under examination. In GreCOR we had no choice but to rely on default values of LTM and EcoTransIT World, the web-based tool used for emission calculations.

The conclusions reached in terms of methodology are summarised below:

Firstly, the method works. After defining GreCOR and setting the boundaries of the analysis, the corridor was decomposed into transport chains, a sample of 156 chains was selected, a set of KPIs was evaluated for each one of these sample chains, the corresponding corridor-level indicators were calculated and an index was produced allowing temporal and modal comparisons for a specific commodity or group of commodities.

Secondly, the use of the SuperGreen methodology, which suggests a spectrum of performance indicators, enabled extending the scope of Activity 3.4 beyond the environmental consequences prescribed in the work description to cover also economic and quality-related aspects of transport operations along the GreCOR corridor.

Thirdly, the application benefited from the advantages of the 'model-based' approach, namely the provision of a comprehensive and coherent picture of all flows on each section of the corridor. It suffered, however, from the absence of a model offering European coverage, having to rely on the Danish LTM model, which imposed undesirable geographic restrictions (only the Oslo-Randstad part of the corridor was examined) and led to diminishing accuracy of results as the distance from Denmark increases.

Fourthly, ensuring reliable data remains a hard problem to address. The service reliability KPI had to be dropped due to lack of data, while the service frequency KPI, although estimated, will probably have to be dropped, too, for the same reason. Furthermore, the reliance on default model values (depending on vehicle type) led to results reflecting solely the modal split aspect of the sample chains. On the contrary, the introduction of raw data solicited from stakeholders to describe the actual conditions of the sample chains would add much more value on the resulting indexes.

8.2 Corridor-specific aspects

There are five points that need to be brought up here. The first one relates to the boundaries of the analysis. Restricting coverage to 'corridor' chains having both ends within the GreCOR catchment area was a decisive step leading to a drastic reduction of chains from 635 to 37 thousand and of annual tonnage from 396 to 17 million tonnes. From the practical point of view, this proved a very useful intervention, as it improved dramatically the manageability of the dataset, without losing potentially interesting transport arrangements. In fact, as mentioned in

Section 5.2, evidence shows that the design of the GreCOR catchment area (and, thus, the 'corridor' chains) has succeeded in capturing the core services of the corridor, placing less emphasis on the feeder services from/to more remote areas.

The second point concerns the composition of the sample. Although a number of criteria were evaluated for constructing the sample, the 'model-based' approach did not permit the exclusion of atypical chains. At the stage of KPI estimation, however, when the chains are looked into more detail, atypical chains may be spotted. The Fredericia-Lübeck connection through a ferry link was such an example. At a second iteration of sample composition, which is missing from the present application, such chains should be omitted.

The third point also relates to sample revision. The size of the sample (156 chains) is considered too big, especially if real data have to be collected from stakeholders. In addition to excluding atypical chains, a second iteration could reduce the sample without much loss in its effectiveness. To do so, a sensitivity analysis is required to check the robustness of corridor-level KPIs in relation to specific chains. Stakeholders may also suggest merging some commodity groups together reducing the number of chains in the sample. The dry bulk Commodity groups 2 (coal & lignite), 3 (iron ore & non-ferrous metal ores) and 23 (stone, sand, gravel & quarry products) are possible candidates.

In terms of modal comparisons, it turns out that a safe way to improve the environmental performance of the corridor is to enhance rail operations, which combine 30% below average GHG and 50% below average SOx emissions with 21% below average cost and almost 55% above average speed. Shipping is also performing well in terms of the environment (34% below average GHG and 7% below average SOx emissions[6]) and very well in terms of cost (57% below average) but the price shippers have to pay comes in speed, which is only half the average value for the corridor.

However, not all shipping sectors share these characteristics. Unlike conventional ships, containerships move cargoes at above average speeds but at extremely high GHG and SOx emissions.

The performance of Ro-Ro shipping in terms of CO_2-eq emissions is even worse but these chains offer the fastest services in the corridor at about 58% above average cost. A little lower speed (still more than 2 times the corridor average) but at a very high cost (3.4 times the

[6] Under the stricter sulphur requirements enforced on Jan. 1, 2015 for the SECAs.

average) is offered by road chains which emit 14% above average GHG and 20% below average SOx. The environmental performance of 3-leg arrangements is not as good as this of their 1-leg counterparts because of the smaller vehicles involved in feeder services.

A final point relates to the composition of trade. Shipping accounts for 70% of the annual tonnage and 75% of the tonne*km of the 'corridor' chains. Therefore, it plays an extremely important role in forming the corridor indexes. It could be of interest to see how the indexes look if calculated on land-based modes only.

8.3 Further actions

The 'model-based' approach followed here could be further improved by:

- Excluding from the sample atypical chains identified during the analysis;
- Revising the sample with the aim of merging commodity groups that use the same type of vehicles and have similar characteristics in terms of the KPIs examined;
- Revising the sample with the aim of excluding chains that do not affect the corridor indexes (when expressed as one decimal point numbers);
- Dropping the frequency indicator from the analysis; and
- Calculating corridor indexes excluding shipping (Ro-Ro ships should not be excluded as they serve road transportation).

What would constitute a major leap forward, though, would be to estimate KPI values at the chain level by obtaining raw data from specialised studies covering specific routes or directly from the stakeholders (shippers, freight forwarders and transport service providers) who use the relevant chains. It is believed that combining the 'model-based' approach for the sample construction with the 'study-approach' for the estimation of chain-level indicators takes advantage of the strengths of each method and avoids their weaknesses.

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References

Books

Psaraftis H.N. (ed.), *Green Transportation Logistics. In Search of Win-Win Solutions*, Springer International Series in Operations Research and Management Science (in press, expected publication August 2015).

Articles & Reports

Arnold J. (2006). *Best Practices in Management of International Trade Corridors*. Trade Logistics Group, Transport Papers TP-13, The World Bank Group, Washington, D.C., December 2006.

CLOSER (2014). *Pilot projects within the GreCOR project*. GreCOR report, Lindholmen Science Park/CLOSER, December 2014.

Corridor A / IQ-C (2011). *6th Progress Report*. Executive Board ERTMS Corridor A and International Group for Improving the Quality of Rail Transport in the North-South Corridor. August 2011.

ETC (2014). *Transport Market Study for the Scandinavian Mediterranean RFC*. Final report, October 2014.

European Parliament & Council (2013a). *Regulation (EU) No 1315/2013 of the European Parliament and of the Council of 11 December 2013 on Union guidelines for the development of the trans-European transport network and repealing Decision No 661/2010/EU*. Strasbourg, 11.12.2013.

European Parliament & Council (2013b). *Regulation (EU) No 1316/2013 of 11 December 2013 establishing the Connecting Europe Facility,* *amending Regulation (EU) No 913/2010 and repealing Regulations (EC) No 680/2007 and (EC) No 67/2010*. Strasbourg, 11.12.2013.

Eurostat (2011). *External and intra-EU trade. A statistical yearbook. Data 1958 – 2010*. Edition 2011.

EWI (2014). *Ecological Transport Information Tool for Worldwide Transports: Methodology and Data Update*. EcoTransIT World Initiative, 4/12/2014.

Fastén G. and Clemedtson P.O. (2012). *Green Corridor Manual.* An East West Transport Corridor II report, NetPort.Karlshamn, 6.7.2012.

Friedrich S. (2012). *Action Programme on the Development of the SCANDRIA Corridor*. A SCANDRIA project report, 2012.

GreCOR (2012). *Action plan for the development of the green corridor: Oslo – Randstad*. GreCOR report, 2012.

GreCOR (2014c). *The GreCOR project. Final conference report*. Swedish Transport Administration, November 2014.

Ibánez-Rivas N. (2010). *Peer review of the TRANS-TOOLS reference transport model*. A JRC Technical Notes report, 2010.

Öberg M. (2013). *Measurement of green corridor environmental impact performance – A2A logistic corridor concept*. A Bothnian Green Logistic Corridor report, June 2013.

Panagakos G. (2012). *Green Corridors Handbook - Volume II.* A SuperGreen project document, 17.12.2012.

Pink B. (2011). *Consumer Price Index: Concepts, Sources and Methods*. Information Paper 6461.0, Australian Bureau of Statistics, 19.12.2011.

Rich J., Nielsen O.A., Brems C. and Hansen C.O. (2010). *Overall design of the Danish national transport model*. Annual Transport Conference, Aalborg University, 2010.

SGCI (2012). *Green Corridors Criteria*. A report of the Swedish Green Corridors Initiative, 8.6.2012.

Stenbæk J., Kinhult P. and Hæstorp Andersen S. (2014). *From speed and transit to accessibility and regional development*. A Green STRING Corridor project report, September 2014.

Swahn M. (2010). *How to evaluate transport's environmental performance*. Article at GreenPort Journal, June 2010.

SWIFTLY Green (2015). *Milestone 7 Report: "First Intermediate Results Finalised from Mapping of Current Status and Projects"*, A SWIFTLY Green project deliverable, January 2015.

TransBaltic (2012). *Macroregional Transport Action Plan*. A TransBaltic project report, 28 August 2012.

Electronic sources

EcoTransIT (2014). http://www.ecotransit.org/ (Assessed: 18.10.2014).

Eurotunnel (2015). http://www.eurotunnelfreight.com/uk/about/fast-and-frequent/ (Assessed: 01.06.2015)

GreCOR (2014a). http://www.grecor.eu/about-grecor/test/ (Assessed: 13.06.2014)

GreCOR (2014b). http://media.grecor.eu/2014/06/Broschure_The-GreCOR-Strategy_June-2014_WEBB_uppslag-.pdf (Assessed: 18.10.2014)

SuperGreen (2015). http://www.supergreenproject.eu/ (Assessed: 28.05.2015)

TENTec (2015a). http://ec.europa.eu/transport/themes/infrastructure/ten-t-guidelines/corridors/doc/scandinavian_mediterranean_map.pdf (Assessed: 01.06.2015)

TENTec (2015b). http://ec.europa.eu/transport/themes/ infrastructure/ten-t-guidelines/corridors/doc/north_sea_baltic_map.pdf (Assessed: 01.06.2015)

Appendix I. Sample structure and KPIs by commodity group

CHAIN TYPE	MODEL RESULTS					SAMPLE			KPIs					KPI Indexes				
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)	COST	SPEED	FREQ.	CO_2-eq	SOx
Commodity group 1A: Agro products - Containerised																		
181	275	2	138	401	110.420													
191	105.744	512	207	382	40.444.344	5	106.020	40.554.764	0,68	29,57	4,81	1.130,28	0,9305	154,0	246,0	9,0	1.618,3	842,9
Total 1A	**106.020**	**514**	**206**	**383**	**40.554.764**	**5**	**106.020**	**40.554.764**	**0,68**	**29,57**	**4,81**	**1.130,28**	**0,9305**	**154,0**	**246,0**	**9,0**	**1.618,3**	**842,9**
Commodity group 1B: Agro products - Non-containerised																		
1	118.563	89	1.332	135	15.994.724													
2	70.060	284	247	432	30.246.147	1	214.583	58.645.910	1,53	28,15	0,44	76,25	0,0854	348,1	234,2	0,8	109,2	77,3
3	12.237	245	50	437	5.348.548	1	15.184	5.994.692	1,65	30,31	0,12	75,38	0,0944	374,8	252,1	0,2	107,9	85,5
5	25.960	29	895	478	12.405.039													
6	2.947	27	109	219	646.144													
111	8.742	40	219	527	4.607.745													
121	18.968	606	31	674	12.783.010	3	31.035	20.260.589	1,45	36,02	0,33	76,80	0,0859	328,5	299,6	0,6	110,0	77,8
131	10.822	622	17	533	5.767.551	3	12.374	6.524.624	1,36	23,66	0,45	104,33	0,1020	308,7	196,8	0,8	149,4	92,4
151	3.326	16	208	863	2.869.835													
161	1.552	18	86	488	757.073													
171	64.627	89	726	703	45.405.452	1	64.627	45.405.452	0,33	16,90	1,52	19,80	0,0234	75,5	140,6	2,8	28,3	21,2
181	1.031.840	181	5.701	631	650.717.227	1	1.031.840	650.717.227	0,16	6,68	8,67	13,10	0,0239	35,5	55,6	16,2	18,8	21,7
Total 1B	**1.369.644**	**2.246**	**610**	**575**	**787.548.494**	**10**	**1.369.644**	**787.548.494**	**0,32**	**11,61**	**6,68**	**21,06**	**0,0313**	**73,5**	**96,6**	**12,5**	**30,2**	**28,3**
TOTAL 1	**1.475.663**	**2.760**	**535**	**561**	**828.103.258**	**15**	**1.475.663**	**828.103.258**	**0,34**	**12,90**	**6,55**	**75,38**	**0,0753**	**77,4**	**107,3**	**12,2**	**107,9**	**68,2**
Commodity group 2: Coal & lignite																		
1	250	1	250	475	118.695													
2	6.754	3	2.251	272	1.840.299	1	7.322	2.138.199	1,55	24,82	11,60	73,47	0,0826	352,4	206,5	21,6	105,2	74,9
3	26	2	13	751	19.705													
5	898	4	224	1.031	925.540	1	910	937.442	1,49	35,82	0,33	72,98	0,0811	338,7	298,0	0,6	104,5	73,5
6	352	4	88	606	213.233	1	413	254.283	0,97	35,86	7,00	94,91	0,0875	220,2	298,3	13,1	135,9	79,2
121	318	2	159	563	179.205													
131	26	2	13	639	16.880													
151	12	5	2	960	11.903													
161	8	4	2	546	4.465													
171	706	25	28	935	659.940	1	706	659.940	0,30	22,87	0,04	14,97	0,0181	67,4	190,3	0,1	21,4	16,4
181	120.743	32	3.773	671	80.976.110	1	120.743	80.976.110	0,13	5,48	6,73	27,86	0,0340	28,6	45,6	12,6	39,9	30,8
TOTAL 2	**130.093**	**84**	**1.549**	**653**	**84.965.974**	**5**	**130.093**	**84.965.974**	**0,18**	**6,97**	**6,93**	**29,60**	**0,0357**	**41,1**	**58,0**	**12,9**	**42,4**	**32,4**

CHAIN TYPE	MODEL RESULTS					SAMPLE			KPIs					KPI Indexes				
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)	COST	SPEED	FREQ.	CO_2-eq	SOx
Commodity group 3: Iron ore & non-ferrous metal ores																		
1	13	1	13	570	7.545													
2	25.006	217	115	385	9.635.129	2	29.949	11.680.386	1,52	23,31	0,38	76,70	0,1027	345,2	193,9	0,7	109,8	93,0
3	4.417	171	26	399	1.763.057	2	5.237	1.861.356	1,68	24,12	0,05	90,13	0,0915	380,4	200,7	0,1	129,1	82,9
5	4.929	10	493	413	2.037.711													
6	821	10	82	120	98.299													
111	89	30	3	556	49.306													
121	4.406	371	12	676	2.978.137	4	4.501	3.034.278	1,92	33,63	0,03	92,97	0,1039	434,8	279,8	0,0	133,1	94,1
131	3.009	385	8	563	1.693.240	4	3.013	1.695.018	1,57	24,37	4,67	80,97	0,0931	356,6	202,7	8,7	115,9	84,4
151	7	4	2	992	6.835													
161	3	2	2	555	1.778													
171	15.417	34	453	653	10.070.128	1	15.417	10.070.128	0,45	9,31	1,61	22,95	0,0192	101,6	77,4	3,0	32,9	17,4
181	278.557	104	2.678	554	154.291.042	1	278.557	154.291.042	0,36	6,86	4,89	38,97	0,0457	80,9	57,1	9,1	55,8	41,4
TOTAL 3	**336.673**	**1.339**	**251**	**542**	**182.632.207**	**14**	**336.673**	**182.632.207**	**0,49**	**9,22**	**4,20**	**42,31**	**0,0497**	**110,5**	**76,7**	**7,8**	**60,6**	**45,1**
Commodity group 6: Wood products - Non-containerised																		
1	19.840	53	374	270	5.356.501													
2	52.559	449	117	387	20.319.057	3	77.961	28.743.852	1,53	25,54	2,88	78,81	0,0810	346,8	212,5	5,4	112,8	73,4
3	13.742	364	38	373	5.122.025	2	14.926	5.456.900	1,54	19,57	0,37	79,40	0,1209	349,9	162,8	0,7	113,7	109,5
5	5.562	18	309	552	3.068.293													
6	1.184	17	70	283	334.875													
111	1.993	16	125	479	955.418													
121	5.959	349	17	664	3.955.657	2	9.273	5.951.492	1,42	36,49	0,39	73,50	0,0809	321,6	303,5	0,7	105,2	73,3
131	3.330	373	9	530	1.763.665	2	3.762	1.925.766	1,88	30,55	2,81	133,87	0,1389	426,3	254,1	5,2	191,7	125,8
151	1.322	6	220	787	1.040.417													
161	433	7	62	375	162.101													
171	19.294	125	154	670	12.936.231	1	19.294	12.936.231	0,34	13,87	4,64	18,06	0,0192	76,5	115,4	8,7	25,9	17,4
181	1.249.917	404	3.094	699	873.143.400	3	1.249.917	873.143.400	0,28	7,20	305,63	20,49	0,0308	63,1	59,9	570,1	29,3	27,9
TOTAL 6	**1.375.133**	**2.181**	**631**	**675**	**928.157.641**	**13**	**1.375.133**	**928.157.641**	**0,34**	**8,73**	**278,04**	**23,19**	**0,0333**	**76,2**	**72,6**	**518,6**	**33,2**	**30,2**

CHAIN TYPE	MODEL RESULTS					SAMPLE			KPIs					KPI Indexes				
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)	COST	SPEED	FREQ.	CO_2-eq	SOx
Commodity group 7: Coke & petroleum products																		
1	42.289	68	622	385	16.260.971	1	42.289	16.260.971	1,54	31,95	1,05	72,25	0,0806	349,2	265,8	2,0	103,4	73,0
2	24.894	54	461	327	8.148.528	1	24.894	8.148.528	1,56	21,36	0,86	73,68	0,0825	354,5	177,7	1,6	105,5	74,7
3	4.212	51	83	386	1.626.667	1	4.212	1.626.667	1,54	28,80	0,21	75,46	0,0965	349,6	239,6	0,4	108,0	87,5
5	698	3	233	988	689.112	1	698	689.112	1,50	36,47	0,29	72,64	0,0803	340,3	303,4	0,5	104,0	72,7
6	86	1	86	820	70.530													
111	11.354	27	421	371	4.211.442	1	11.354	4.211.442	1,49	35,73	1,17	72,61	0,0819	338,3	297,2	2,2	104,0	74,1
121	1.250	50	25	728	909.418	1	1.250	909.418	3,08	38,63	0,04	176,71	0,1976	698,9	321,4	0,1	253,0	179,0
131	791	48	16	692	547.503	1	791	547.503	1,60	19,73	0,04	79,89	0,0899	363,0	164,1	0,1	114,4	81,4
151	1.172	15	78	875	1.025.795	1	1.172	1.025.795	1,38	34,34	0,04	84,52	0,0951	313,4	285,7	0,1	121,0	86,1
161	1.040	13	80	613	637.202	1	1.126	707.732	0,64	33,81	2,00	118,59	0,0892	144,7	281,3	3,7	169,8	80,8
171	10.018	48	209	669	6.705.888	1	10.018	6.705.888	0,35	15,12	0,50	16,28	0,0205	79,5	125,8	0,9	23,3	18,6
181	3.351.751	108	31.035	598	2.004.408.771	2	3.351.751	2.004.408.771	0,13	4,00	80,93	9,79	0,0206	30,1	33,3	151,0	14,0	18,7
TOTAL 7	**3.449.555**	**486**	**7.098**	**593**	**2.045.241.826**	**12**	**3.449.555**	**2.045.241.826**	**0,16**	**4,68**	**78,66**	**10,93**	**0,0217**	35,7	38,9	146,7	15,6	19,7
Commodity group 14: Secondary raw materials & wastes																		
1	23.563	79	298	372	8.770.501	1	23.563	8.770.501	1,53	22,26	0,38	72,92	0,0817	346,7	185,2	0,7	104,4	74,0
2	29.082	334	87	399	11.594.055	1	29.469	11.847.197	1,49	26,55	0,19	73,10	0,0820	339,0	220,9	0,4	104,7	74,3
3	5.297	248	21	355	1.880.686	1	5.410	1.928.889	1,55	26,19	0,13	76,44	0,1020	350,5	217,9	0,3	109,4	92,4
5	387	2	193	655	253.142									0,0	0,0	0,0	0,0	0,0
6	113	2	57	425	48.203									0,0	0,0	0,0	0,0	0,0
111	910	19	48	475	431.679									0,0	0,0	0,0	0,0	0,0
121	6.355	730	9	567	3.604.207	2	7.264	4.035.885	3,47	27,77	0,03	124,94	0,1403	786,4	231,1	0,1	178,9	127,1
131	3.987	735	5	423	1.687.062	2	3.987	1.687.062	2,80	14,56	12,67	122,73	0,1143	636,1	121,2	23,6	175,7	103,6
171	5.152	76	68	634	3.267.061	1	5.152	3.267.061	0,31	16,90	0,17	15,46	0,0182	69,9	140,6	0,3	22,1	16,5
181	451.679	229	1.972	709	320.319.122	1	451.679	320.319.122	0,16	5,60	3,57	13,06	0,0234	35,4	46,6	6,7	18,7	21,2
TOTAL 14	**526.522**	**2.454**	**215**	**668**	**351.855.718**	**9**	**526.522**	**351.855.718**	**0,30**	**8,21**	**3,19**	**18,75**	**0,0290**	**66,9**	**68,3**	**5,9**	**26,9**	**26,2**
Commodity group 15: Mail & parcels																		
1	3.113	2	1.556	55	170.960													
2	172.439	101	1.707	429	73.932.941	1	175.552	74.103.901	1,53	32,13	2,93	73,51	0,0822	348,1	267,3	5,5	105,3	74,5
3	25.616	78	328	517	13.236.886													
111	3.600	2	1.800	305	1.097.589													
121	74.865	737	102	622	46.572.659	3	78.465	47.670.248	1,67	28,01	0,24	85,74	0,0960	379,5	233,0	0,4	122,8	87,0
131	45.273	754	60	553	25.026.958	3	70.889	38.263.843	1,23	22,69	4,18	117,78	0,1093	279,8	188,7	7,8	168,6	99,0
181	28	14	2	579	16.208													
191	51.319	389	132	303	15.547.668	2	51.347	15.563.877	1,64	30,65	12,25	131,96	0,1344	371,2	255,0	22,8	188,9	121,7
TOTAL 15	**376.253**	**2.077**	**181**	**467**	**175.601.869**	**9**	**376.253**	**175.601.869**	**1,52**	**29,29**	**3,88**	**91,66**	**0,0965**	**343,8**	**243,7**	**7,2**	**131,2**	**87,4**

CHAIN TYPE	MODEL RESULTS					SAMPLE			KPIs					KPI Indexes				
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)	COST	SPEED	FREQ.	CO_2-eq	SOx
Commodity group 21: Crude oil & natural gas																		
2	14.084	9	1.565	311	4.380.337	1	14.084	4.380.337	1,81	27,95	0,27	97,87	0,1099	409,4	232,5	0,5	140,1	99,6
3	906	8	113	427	387.415													
121	1.009	11	92	730	736.151	1	1.098	829.091	1,69	22,86	0,04	92,30	0,0996	383,5	190,2	0,1	132,1	90,3
131	392	11	36	610	239.391	1	1.364	667.484	1,60	19,73	0,04	80,10	0,0896	363,1	164,1	0,1	114,7	81,2
151	89	7	13	1.043	92.940													
161	66	7	9	620	40.678													
171	34.806	20	1.740	618	21.517.848	1	34.806	21.517.848	0,36	17,79	0,13	14,50	0,0190	81,7	148,0	0,3	20,8	17,2
181	1.150.361	28	41.084	528	607.689.329	1	1.150.361	607.689.329	0,41	6,05	117,98	27,14	0,0375	91,9	50,3	220,1	38,9	33,9
TOTAL 21	**1.201.714**	**101**	**11.898**	**528**	**635.084.089**	**5**	**1.201.714**	**635.084.089**	**0,42**	**6,68**	**112,95**	**27,34**	**0,0375**	**94,4**	**55,5**	**210,7**	**39,2**	**33,9**
Commodity group 22: Fertilizers																		
1	2.250	9	250	453	1.019.240													
2	18.462	100	185	502	9.275.328	1	21.259	10.889.129	1,54	31,48	3,18	73,89	0,0818	348,4	261,9	5,9	105,8	74,1
3	3.515	82	43	564	1.980.694	1	3.601	2.047.783	1,50	30,58	0,31	75,21	0,0937	339,4	254,4	0,6	107,7	84,9
5	547	2	274	1.087	594.561													
6	86	1	86	780	67.088													
111	47	10	5	423	19.870													
121	7.335	422	17	664	4.867.086	4	8.904	6.321.915	1,54	27,79	0,04	82,78	0,0931	350,0	231,2	0,1	118,5	84,3
131	4.539	428	11	633	2.874.265	4	5.971	3.600.961	1,49	20,93	2,64	117,37	0,1157	337,3	174,1	4,9	168,1	104,8
151	1.522	12	127	943	1.434.959													
161	1.433	13	110	507	726.696													
171	4.642	16	290	982	4.556.469	1	4.642	4.556.469	0,33	21,43	2,70	15,41	0,0186	75,4	178,3	5,0	22,1	16,8
181	9.588	21	457	684	6.555.747	1	9.588	6.555.747	0,14	7,23	4,45	12,01	0,0228	31,1	60,2	8,3	17,2	20,7
TOTAL 22	**53.964**	**1.116**	**48**	**630**	**33.972.003**	**12**	**53.964**	**33.972.003**	**1,10**	**24,47**	**2,60**	**60,45**	**0,0683**	**249,1**	**203,6**	**4,8**	**86,6**	**61,9**
Commodity group 23: Stone, sand, gravel & quarry products																		
1	9.134	35	261	266	2.429.037	1	9.134	2.429.037	1,71	7,35	0,46	73,27	0,0810	387,2	61,2	0,9	104,9	73,4
2	34.705	360	96	365	12.658.911	2	36.186	13.743.742	1,57	20,89	0,35	73,48	0,0823	355,5	173,8	0,6	105,2	74,5
3	11.032	323	34	328	3.615.123	2	11.401	3.772.334	1,40	24,17	0,07	77,13	0,1061	317,0	201,1	0,1	110,4	96,1
5	1.480	10	148	733	1.084.831													
6	369	7	53	426	157.211													
111	6.136	34	180	367	2.254.940													
121	2.955	437	7	646	1.908.015	3	10.553	5.339.739	2,01	36,24	0,05	79,67	0,0891	455,3	301,5	0,1	114,1	80,7
131	1.791	430	4	546	978.736	3	2.429	1.226.326	8,10	24,61	0,02	111,47	0,1373	1.837,4	204,7	0,0	159,6	124,3
151	1.462	17	86	805	1.176.785													
161	638	18	35	388	247.590													
171	9.786	56	175	726	7.101.836	1	9.786	7.101.836	0,33	15,22	0,36	18,05	0,0212	75,8	126,6	0,7	25,8	19,2
181	193.735	120	1.614	582	112.756.260	1	193.735	112.756.260	0,15	7,97	3,72	29,79	0,0359	33,2	66,3	6,9	42,7	32,5
TOTAL 23	**273.223**	**1.847**	**148**	**536**	**146.369.274**	**13**	**273.223**	**146.369.274**	**0,48**	**11,83**	**2,72**	**37,77**	**0,0449**	**109,3**	**98,4**	**5,1**	**54,1**	**40,7**

CHAIN TYPE	MODEL RESULTS					SAMPLE			KPIs					KPI Indexes				
	Annual tonnes	No of chains	Tonnes per chain	Average Distance	Tonne*km	No of chains	Adjusted tonnes	Adjusted tonne*km	COST (DKK/tkm)	SPEED (km/h)	FREQUENCY (serv./week)	CO_2-eq (g/tkm)	SOx (g/tkm)	COST	SPEED	FREQ.	CO_2-eq	SOx
Commodity group REST A: Various - Containerised																		
171	36.427	103	354	876	31.892.871	1	36.427	31.892.871	0,61	40,83	2,88	328,79	0,3722	138,4	339,7	5,4	470,8	337,2
181	1.509.229	1.024	1.474	682	1.029.596.551	5	1.509.229	1.029.596.551	0,23	12,95	41,27	250,66	0,6025	53,3	107,8	77,0	358,9	545,8
191	238.878	1.632	146	455	108.788.252	8	238.878	108.788.252	0,72	27,49	9,46	1.081,05	0,9230	162,9	228,7	17,6	1.547,8	836,1
Total RA	**1.784.535**	**2.759**	**647**	**656**	**1.170.277.674**	**14**	**1.784.535**	**1.170.277.674**	**0,29**	**15,47**	**36,23**	**329,98**	**0,6260**	**65,8**	**128,7**	**67,6**	**472,5**	**567,1**
Commodity group REST B: Various - Non-containerised																		
1	220.998	349	633	214	47.262.316	1	220.998	47.262.316	1,70	7,95	13,48	73,02	0,0800	386,6	66,1	25,1	104,5	72,4
2	1.001.773	1.471	681	438	438.825.403	2	1.108.526	521.172.000	1,55	25,24	31,33	73,46	0,0822	351,7	210,0	58,4	105,2	74,5
3	229.608	1.232	186	483	110.933.903	2	229.608	110.933.903	1,52	21,45	5,69	79,34	0,1140	343,8	178,4	10,6	113,6	103,3
5	106.753	160	667	771	82.346.597													
6	41.698	147	284	512	21.337.819	1	107.209	54.827.834	0,92	34,21	7,00	97,09	0,0866	208,6	284,6	13,1	139,0	78,4
111	192.037	493	390	416	79.820.022	1	192.037	79.820.022	1,48	28,39	0,46	73,23	0,0820	335,4	236,2	0,9	104,9	74,3
121	317.653	5.346	59	650	206.485.271	9	317.653	206.485.271	1,57	35,18	1,88	79,16	0,0889	356,2	292,7	3,5	113,3	80,5
131	222.706	5.512	40	551	122.710.376	9	222.706	122.710.376	1,37	21,38	2,81	99,21	0,1011	311,2	177,8	5,2	142,0	91,6
151	126.846	347	366	877	111.230.026	1	126.846	111.230.026	1,49	36,84	15,34	73,50	0,0822	337,1	306,5	28,6	105,2	74,5
161	65.511	334	196	511	33.490.015													
171	215.634	1.022	211	793	171.097.420	2	215.634	171.097.420	0,30	16,78	12,88	16,17	0,0188	67,9	139,6	24,0	23,2	17,0
181	2.755.719	263	10.478	656	1.806.849.476	1	2.755.719	1.806.849.476	0,11	4,11	1,00	8,56	0,0194	25,8	34,2	1,9	12,3	17,6
191	756.889	3.566	212	523	396.109.104	6	756.889	396.109.104	0,66	27,94	7,24	116,52	0,0914	148,8	232,4	13,5	166,8	82,8
Total RB	**6.253.825**	**20.242**	**309**	**580**	**3.628.497.747**	**35**	**6.253.825**	**3.628.497.747**	**0,66**	**16,07**	**8,64**	**44,87**	**0,0510**	**150,0**	**133,7**	**16,1**	**64,2**	**46,2**
TOTAL R	**8.038.360**	**23.001**	**349**	**597**	**4.798.775.421**	**49**	**8.038.360**	**4.798.775.421**	**0,57**	**15,93**	**14,77**	**114,40**	**0,1912**	**129,5**	**132,6**	**27,5**	**163,8**	**173,2**
GRAND TOTAL	**17.237.155**	**37.446**	**460**	**592**	**10.210.759.280**	**156**	**17.237.155**	**10.210.759.280**	**0,44**	**12,02**	**53,61**	**69,84**	**0,1104**	**100,0**	**100,0**	**100,0**	**100,0**	**100,0**

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The Interreg IVB North Sea Region Programme
Investing in the future by working together for a sustainable and competitive region

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